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PHYSICAL REJECTION FOR MILITARY SERVICE; SOME PROBLEMS OF RECONSTRUCTION

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THE draft has been a great inventory of the resources of the nation—it has shown both our physical assets and our human liabilities. The material was found to be of good grade; but 29.11 per cent. of the registrants were rejected by the physicians of the local boards and 5.8 per cent. by the camp surgeons as physically unfit for general military service, a total of 34.19 per cent.

The first draft was necessarily a rather coarse, hurried sifting of the fit from the unfit, and usually did not go beyond the defect sufficient to warrant rejection. The large percentage of abnormalities discovered in men from twenty-one to thirty-one years of age is the rate of the determining cause of rejection and is inconclusive as to the coexistence of other surgical or pathological conditions. For example, for such causes as hernia, goiter or flat foot, quickly discovered defects, the statistics of the draft boards are convincing, but for tuberculosis in individuals with goiter or heart disease in men with hernia, they are incomplete.

The evidence available indicates fifty to sixty per cent. of the men between thirty-one and forty-six years of age could not have passed for general military service if the physical requirements had remained unchanged.

The physical findings of the first draft to the public has proved an unpleasant revelation; to the student of preventive medicine the fulfilment of a prophecy. An examination of the causes of rejection in reference to origin and manner of development shows that many could have been easily prevented, readily corrected, or promptly cured. In fact, we are so far

beneath our ability to increase the vigor, efficiency and happiness of the race as to appear to be still within the shadows of the dark ages.

Causes for Physical Disqualification by Camp Surgeons

It should be borne in mind that the statistics of the Report of the Provost Marshal General are based upon ten thousand two hundred fifty-eight records spread over eight camps. The percentage of disqualification at camp varied between seventy-two hundredths per cent. to eleven and eighty-seven hundredths per cent. (average five and eight tenths per cent.) under the first draft, which was smaller than the national average (seven and six tenths per cent.) for the period February 10 to September, 1918. The variation is due both to differences in standards observed by examining surgeons, and to the region of the country from which the recruits are drawn.

TABLE I

Causes for Physical Rejection by Camp Surgeons—National Army Experience Under First Draft of the Selective Service Act of 1917

Causes for Physical Rejection	Number	Per Cent.
Eye	2,224	21.68
Teeth	871	8.50
Hernia	766	7.47
Ear	609	5.94
Heart disease	602	5.87
Tuberculosis	551	5.37
Mentally deficient	465	4.53
Genito-urinary (venereal)	438	4.27
Physical undevelopment	416	4.06
Nervous disorders (general and local)	387	3.77
Flatfoot	375	3.65
Joints	346	3.37
Bones	304	2.96
Blood vessels	191	1.86
Underweight	163	1.59
Respiratory	161	1.56
Genito-urinary (non-venereal)	142	1.39
Skin	118	1.15
Ill-defined or not specified	93	.91
Digestive	82	.80
Alcoholism and drug habit	79	.77
Muscles	66	.64
Not stated	809	7.89
Total number of cases of physical rejections considered	10,258	100.00

Table I. shows that thirty-six and twelve hundredths per cent. of all rejections were due to defects of the eye, the ear and the teeth; eleven and twelve hundredths per cent. to hernia and flat foot; five and sixty-five hundredths per cent. to underdevelopment and underweight; five and thirty-seven hundredths per cent of the total to tuberculosis.

We need only to consider the causes of disqualification for military service in connection with the physical defects of school children to see the close relation of the one to the other.

Diseases and Defects of the Eye

Over one fifth (twenty-one and sixty-eight hundredths per cent.) of the physical disqualifications for military service was due to disease of the eye. Gonorrhea, syphilis, trachoma and the accidents of carelessness and ignorance—preventable causes—are responsible for forty per cent. of all blindness. Eliminate these and we may close four of every ten of our institutions for the blind and use their maintenance funds for a necessary charity.

As causes of impaired vision, uncorrected astigmatism, short-sightedness and squint aggravated by close work are of the first importance. Dufour has shown that the number of pupils with myopia and the average degree of shortsightedness increase from class to class and with the addition in school demands. This form of myopia is usually primarily due to congenital astigmatism, a very common condition, and the consequent strain upon the accommodation of the eye in the effort to see. Risley has reported a series of cases in which astigmatic eyes had passed, while under his observation, from hypermetropic to myopic refraction.

Neglected squint is an important factor in the serious impairment and destruction of vision. The bad advice to parents that the child beginning to squint will grow out of it, frequently has led to delay until the eye was blind. If the serious consequences of procrastination were known, children would be no more neglected than if they had appendicitis or diphtheria.

Rigid enforcement of the law relative to safeguarding the eyes at birth and to the control of venereal diseases and trachoma will save many eyes. Workers in occupations where eye injuries are common should be required to use proper methods of protection. No child should be permitted to begin school until his eyes have been examined by a competent oculist. When, for economic reasons, parents are unable to have him consult an ophthalmologist, the school board should make pro-

visions for his eye examinations. It will be better for society and cheaper for the state to provide glasses to correct errors of refraction than to bear the expense of class repetition, retardation or the result of delinquency, to which the eye defect may be a secondary but determining factor.

Diseases of the Ear

Diseases of the ear were responsible for five and ninety-four hundredths per cent. of the rejections. With few exceptions, auditory defects were the reason for disqualification. Middle-ear disease, which causes eighty-five to ninety per cent. of all deafness, usually has its origin in the nasopharynx and the Eustachian tube. Approximately thirty per cent. of the deafness in the United States is due to the suppuration of the middle ear during childhood. Ten per cent. of the discharging ears of children are complications of scarlet fever, measles, or other communicable diseases; in ninety per cent. diseased tonsils and adenoids are predisposing causes. In a systematic oral examination of patients with adenoids, Tomlinson found some grade of ear involvement in seventy-five per cent.

Where the function of hearing is impaired, the mentality of the child suffers. He becomes inattentive, in many instances diffident, and frequently a class repeater. Partial deafness, especially when it dates from childhood, is a disadvantage that seldom permits the individual to attain the efficiency of which he would be otherwise capable.

Much deafness would be avoided if diseases of the ear were promptly treated by specialists and if parents would see that the adenoids and enlarged tonsils of their children received proper attention. Medical inspection of schools and free treatment for children with disease of the nose, throat and ear whose parents are unable to provide medical care for them should be an important part of any program for the prevention of deafness.

Defective and Carious Teeth

Rejection of eight and five tenths per cent. of the registrants on account of their teeth occasions no surprise in a nation where decayed teeth is a disease of the masses and where seventy to ninety per cent. of school children have defective teeth. Had military requirements of previous wars been observed, a much larger per cent. would have been disqualified. The loss of a number of teeth both causes deformity of the face and impairs digestion by decreasing the ability of the individual to

masticate his food. The pus pockets and root abscesses are a serious menace to general health.

Instruction in oral hygiene, the examination of teeth of school children at least twice a year and a public clinic for the benefit of those unable to consult a private dentist would give the coming generation a digestion, a set of teeth, and a beauty of countenance unequaled by any of its predecessors.

Hernia

Hernia was the cause of seven and forty-seven hundredths per cent. of all rejections. A number of the ruptures encountered are congenital or are superinduced by anatomical abnormalities. Chronic constipation, faulty posture, lack of exercise and improper clothing, with resulting flabby abdominal muscles, and sudden strain are important factors in its production. Hernia to a considerable degree is preventable. Its presence is proof of neglected surgery.

Flat Feet

If flat feet were considered and treated with reference to their predisposing causes, physical rejection on their account would be much less than three and sixty-five hundredths per cent. Flat feet should be recognized as weak feet before flattening of the long arch has developed and the usual train of symptoms are present. The body weight normally passes slightly to the inner side of the center of the knee, through a line prolonged from the crest of the tibia, through the ankle, over the dorsum of the foot to the second toe. With the beginning of eversion of the foot and the change of direction of the body weight, it is only a question of time before the symptoms and signs of flat foot become evident.

The importance of muscle insufficiency, improper nutrition and communicable disease in the production of flat foot are shown in the following table, taken from the statistics of Ehrenfried:

Children under twelve years of age examined	1,000
Children with debility of the feet	440
Congenital—club-foot	18
Idiopathic—physical debility	95
Secondary, due to some other condition	327
A. Rickets	200
B. Cases of unsuspected infantile paralysis	107

Undevelopment and Underweight

It creates no surprise that poor general physical condition accounted for five and thirty-seven hundredths per cent. of the rejections, when it is known that from fifteen to twenty-five per cent. of the school children suffer from malnutrition. Defective sight, deafness, difficult breathing caused by adenoids and nasal obstructions, enlarged tonsils, contagious diseases, and insanitary home surroundings are preventives and deterrents of normal growth.

Regardless of whether physical subnormality is an expression of one or a combination of these causes, it is preventable and correctable. Its presence in a large per cent. of the population is a reflection on our civilization and a menace to the future welfare of the nation. An efficient system of child welfare, medical inspection of schools, school lunches and physical education throughout school attendance would insure the proper development of children to adults. An attempt to teach an undernourished child is an attempt to decorate before laying the foundation. The small cost of the school lunch, in most instances, should be borne by the child; if necessary, it should be paid for by the school. The better work of the child and the instructional value of the lunch would well repay the trouble of preparation and the expense.

The same undevelopment, bad home conditions and physical handicaps which contribute so largely to the production of sub-standard individuals create pressing problems for the teacher, the physician, the sociologist and the penologist. The physically defective individual, denied his inalienable rights of adequate food, healthful environment and proper medical care falls an easy prey to disease, may develop anti-social tendencies, or, as industrial flotsam, often settles along the shores of endeavor, a hindrance to the launching of enterprise.

Physical Defects and Delinquency

The loss or impairment of an organ destroys or decreases the efficiency of the harmonious interaction of the other organs of the body, and continued existence is the result of readjustment. The resulting reaccommodation not only affects the physical personality, but it may also give rise to deviation from normal mental reaction. We are unable to estimate the exact part played by defects of the ears and eyes, diseased tonsils and adenoids, in the production of truancy and delinquency. Neither are we able to determine the relation of undernutrition and anemia to incorrigibility. We do know, however, that physical

defects and undernourishment may be the precipitating cause, when associated with such contributing factors as defective ancestral germ-plasm and oppressive environment. One individual in good surroundings and well nourished, with a stable nervous system, may survive the misfortune of his physical handicap; while a physical defect in another with an already overtaxed brain may produce such nervous irritation as to give rise to mental abnormality or antisocial tendencies.

Physical Fitness of Women

While we have available no such extensive statistics for women as for men, fragmentary evidence and comparison of the findings of the medical inspectors of schools in the case of boys and girls do not indicate that women are of better general physique than men. All the major causes for physical disqualification under the draft are by no means peculiar to the male and may occur in the female. The first draft, therefore, may also be considered a more or less accurate index of the physical development and defects of the women of the nation between the ages of twenty-one and thirty-one. From the view-point of racial vitality and progress the physical development of women is as essential as that of men—the prevention of disease and physical handicaps perhaps of greater importance.

Lest We Repeat

A survey of the causes of physical disqualification in men twenty-one to thirty-one years of age does not warrant extreme pessimism in regard to the physical deterioration of the manhood of the nation, as a number of the defects are anatomical, largely preventable, and do not indicate substandard general physical condition. They are, however, an overwhelming, unanswerable argument for the immediate adoption of a comprehensive system for the promotion of child welfare, for the medical supervision of schools, for instruction in hygiene, and for thorough physical training.

In this country 230,000 infants die annually. Before the war an infant had six or seventeen chances in a hundred of dying in the first year, depending on whether its father earned over twelve hundred fifty dollars or under four hundred fifty. One baby in twenty-five dies from diseases directly due the care and condition of its mother during pregnancy and confinement. The death rate among infants whose mothers go out to work is twice that of those whose mothers are able to remain at home

and care for them. Thousands of infants weather the first years of life battered and weakened, forever handicapped in becoming effective members of society. Poverty and ignorance underfeed from fifteen to twenty-five per cent. of the children of the nation. Tens of thousands of human beings are being reared in insanitary surroundings in which it is impossible for them to attain normal growth and health.

In spite of its importance, required systematic learning of hygiene, sanitation and physiology is an exception, even in our institutions of higher learning. The present legal requirements for these subjects in the elementary and secondary schools are inadequate and are in great need of immediate revision. Mind embellishment takes precedence over that knowledge which would safeguard health and prevent the loss of life. A system of education that does not prevent its finished product from blistering his arm with a pepper plaster or from pouring sulphur in his shoes to avoid influenza is no more successful than one that permits a student to graduate without a knowledge of mathematics or of language. The draft has taught that in developing a child the gymnasium and library, the classroom and the playground, the laboratory and the great outdoors are coordinate. It has shown that in moulding efficient citizens to support the nation in its hour of need the lowly sandwich, served in a school lunch room, and fresh air may be as valuable as the "rule of three." In other words, social effectiveness is equally dependent upon adequate mental and physical development. The most valuable individual to the state is he in whom the moral, physical and mental qualities are most highly developed, absolutely correlated and in perfect harmony. The need of the hour is that physiology, sanitation, hygiene and physical training should have place in our educational system, commensurate with their importance to the individual and to society.

Medical Inspection of Schools

Medical supervision of schools should include a school nurse service. It should apply to buildings and equipment, as well as to the mind and body of the children. About twenty million children, nearly one third of the population of the country, are compelled to spend, on an average, five hours a day in school one hundred sixty-five days in the year. Under such circumstances, as effective precautions should be taken to insure proper ventilation, lighting, heating, furniture and general sanitary conditions in the school as to provide for the child's physical welfare as to enforce its attendance. It is obviously unfair to re-

quire a child to occupy a seat likely to produce body deformity or to study in a light that may impair its vision, yet this is done throughout the nation. It is equally unjust to bring together a number of young persons at an age when most susceptible to communicable diseases without medical supervision, unless the school is to provide a great disease exchange for the community. In this connection it must be remembered that the twenty million children of elementary-school age come in contact, more or less intimately, with approximately twelve million others of preschool age. These younger children are very susceptible to infectious diseases and are in the age group in which eighty-five per cent. of the mortality occurs.

When medical inspection is carried out, a disease history of the child will be obtained on entry, and an enormous number of defects and functional diseases will be discovered that may be corrected. It will provide a careful medical record preliminary to physical training, will determine in what individual corrective gymnastics are needed, and, by its periodical examination, will ascertain the physical progress of the child. The community should realize, however, that it is of little value to spend money to discover defects unless provision is made to remedy them when they are found. Each school district should provide a dispensary service for school children and parents must be educated to save themselves expense by paying the family doctor a small sum to prevent, rather than a large sum to cure, illness in their children.

Physical Education

Physical education should have as its purpose the development of the functional power of the child to the highest level consistent with the most successful training of its intellect; it should meet the needs of the weak, who require it most, as well as of the strong; it should be graded for various ages; its progress should be determined by tests and measures of development, strength, agility, endurance and ability to do. Its proficiency should be based upon well-defined accomplishments and not upon one or two periods of exercise for a given time.

In general, provision must be made for the physical education of three classes of individuals: (1) the physically normal, (2) the subnormal, (3) the abnormal and physically defective.

The physically normal should not only be required to take general exercise, but should be encouraged to select some form of sport and to acquire a fondness for it. In the primary school it may mean games and outdoor exercise; in the high school or

college the development of an "athletic hobby" to keep him in "fighting trim" when required to lead a sedentary life.

The subnormal individual, underweight and understrength for his age, undeveloped but organically sound, will require special and general exercise to meet the tests of normal. Having shown his ability by passing the required efficiency tests of normal, he may be further educated as in the first class.

In the abnormal group we find individuals distorted as to posture or carriage, but who may become greatly improved or who may overcome their deformity by corrective gymnastics. In this class we also have the cripples and those with heart lesions, hernia, diseases of the joints, etc. A number of these individuals could be cured by proper surgery, and would be, if their parents were so advised by a medical inspector in whom they had confidence. All would be greatly benefited by special calisthenics and other light forms of exercise under medical supervision. In many instances members of this group have been led to attach too much importance to their condition. Nothing will do more than safe, beneficial exercise to lift them from the despair of chronic invalidism to the enthusiasm of physical well-being.

Physical education is a great antidote for antisocial tendencies. It teaches temperance, self-control, courage and endurance. It produces the ability to play the game to the end and to lose with a smile or to take victory with modesty and magnanimity. It Americanizes and de-hyphenizes by the democracy of the playground and by the catholicity of its games. It places the nation on the solid foundation of physical soundness, morality and vitality.

Reconstruction must mean a new day, a new courage—a new justice. Education must be revised to cultivate properly the body as well as the mind. The slaughter and crippling of infants by atrocious social conditions must cease. The underfed must be adequately nourished; children physically handicapped must receive medical care when the greatest number of cures are possible. The treatment of mental defectives must be inspired by scientific common sense rather than by ignorant and foolish sentiment. Living conditions must be those in which a human being can best live, grow and work.

THE EUGENIC ASPECT OF SELECTIVE CONSCRIPTION

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THE future of a nation depends to a certain extent upon the relative quality of those who survive a war and those who perish. Coming generations are produced in larger part by the non-combatant males, since a certain fraction of the combatants never return, and of those who do return, some are so incapacitated as to prevent marriage and parenthood. It therefore behooves us to inquire whether the method of selecting the group for this high percentage of mortality is such that the individuals are on the average higher than the average of the remainder of the same age and sex, or that they are of average quality, or that they are inferior. It is because this tremendously important question, which means so much to the future of our race, seems to have been viewed wholly from the standpoint of military efficiency, and administrative convenience, that it is desirable to consider here the neglected eugenic aspect.

First we must compare the eugenic results of enlistment *vs.* selective conscription. Voluntary enlistment is a definitely selective process, no less selective because it is by the will of the individuals. The individuals who have the will to enlist differ in the long run from those who do not have the will to enlist. Furthermore, this will to enlist is associated in different wars with different qualities. In the Spanish War it is probable that the love of adventure played a larger part on the whole than in the Civil War or the Great War. When a country is not suffering invasion the enlistments are of a somewhat different type of men from when it is. What is especially important for our purpose is a consideration of the extent to which idealism is effective. The more idealistic the aims of a war, the more important it is that selective conscription should replace enlistment early and completely.

Conceding then the superiority of selective conscription, what should be the basis of selection, having reference both to military efficiency and to post-bellum results?

Arbitrary limits of little selective importance should be

avoided, as the larger the range from which one may select, the more discriminating the possible selection. Thus the draft age limit should have been from 19 to 40 years from the outset of the Great War. The exemption of the married, however, so long as military exigencies permit, is desirable from a eugenic standpoint as well as from various social and military considerations.

Exemptions on physical grounds are of course necessary for military reasons, but except for certain defects of no eugenic significance, should be kept as few as feasible, for such exemptions on the whole have a dysgenic effect by lowering the relative mortality of the exempts, since their physical inferiority would be in some cases inherited to some degree. The exemption of those suffering from diseases or defects which are curable without too great an expense or too long a period should be discontinued, and an attempt should be made to restore such cases in special restoration camps. Otherwise some inferior groups will contribute unduly to the next generation.

But it is of course the mental (including the moral) attributes which are of major concern from the standpoint of post-bellum results. Necessarily there must be an exemption of the highly unsuitable or markedly mental defective since their uncertain conduct might endanger the lives of their associates. On the other hand, the exemption of the merely dull-minded who can be useful in digging, carrying and handling supplies under supervision would be a serious error by saving for survival this group at the expense of their superiors.

Second, where a type of service or a detail for a special purpose is especially hazardous, selection should be for the special qualities needed and should exclude those who are also highly superior in a wide range of qualities which are not needed. It is at this point that the current methods are most faulty. For instance, in the aviation service, the candidate, besides passing some necessary physical tests, must in general have been a college student. Mental tests for special qualities needed in aviation should be elaborated at once to supplant the present crude and socially and racially damaging method of selection.

While selection for especially hazardous tasks by volunteering can not be wholly abandoned, in general, the officers should select the men with reference to the particular quality needed for the particular assignment and should avoid choosing men who are far better for other assignments, but not better for the assignment in question.

Officers must necessarily be a select group for reasons of military efficiency. For this same reason, the enemy wishes to eliminate them. Care should therefore be taken to conceal their identity when exposed to the enemy, and to limit such exposure in so far as military efficiency permits. Officers of no higher rank than necessary should be permitted to accompany small parties on extra hazardous details.

The use of the present questionnaire for the selection of draftees is vastly superior to the far cruder method at first employed. Especially to be commended from the eugenic as well as the social standpoint is the placing of technical experts and important executives in late classes.

Unfortunately in the stress of war needs there is a natural tendency to lose sight of ultimate results at the very time when such results are most seriously at stake.

The Trail through the Rain Forest beneath the Moss, beside the Ferns.

THE FERNS OF THE RAIN-FOREST

By CLIFFORD H. FARR, Ph.D.

WILLIAM BAYARD CUTTING TRAVELING FELLOW OF COLUMBIA UNIVERSITY

THE marvel of the vegetation of the tropical rain-forest is the tree-fern. A tree in form and size and a fern in structure, this plant has been indeed aptly named. Its stem stands erect in the midst of the jungle to a height of fifty feet in some instances, and its few large leaves form a crown at the top very much like that of the palm. But tree-ferns are even more beautiful than the royal palm, the most stately of that group. The leaves are more finely divided, delicate and lace-like, and are arranged in a perfect rosette; and the stem, far more slender and graceful, has its surface moulded into a unique pattern as if in terra cotta.

Tree-ferns are exceedingly choice in selecting their dwelling places, and refuse to endure any sort of rigorous environment. In fact, they grow in the most evenly tempered climates in the world. The average temperature of their habitat in Jamaica is about sixty degrees Fahrenheit, and no variation of

THE LARGE-LEAVED *Alsophila pruniata.*

Looking up a ravine.
Climbing Ferns to the right.

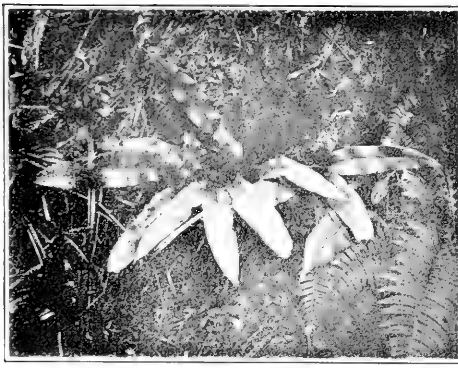
more than sixteen degrees above or below occurs throughout the entire year. There are thus no cold winters nor hot summers with which to contend; and likewise there are no long periods of drought usually, for the tree-fern grows where it rains almost every day. The moisture-laden trade winds strike against the north side of the Blue Mountains of Jamaica at an elevation of about one thousand feet and slowly creep up their slopes, the moisture precipitating as it cools. It is on such slopes as these, at an altitude of about five thousand feet, that the tree-fern is at its best. Here the minimum annual rainfall is about sixty inches and the maximum about two hundred. Not only does the tree-fern require a very moderate temperature and a large amount of moisture both in the soil and air, but it is also not adapted to withstand strong winds. Its slender, unbranched stem, only two or three inches thick and many feet in height, is extremely frail in comparison with the trunks of other trees. Consequently, it must hide itself in the

depths of narrow ravines through which only gentle zephyrs move. Nor does the direct intense light of the tropical sun usually fall upon most members of this group through long periods, for other trees and perpetually veiling clouds shield them from its actinic rays. Despite the fact that light is an essential to plant activity, these curious forms, unlike other trees, do not continue to flourish when direct sunlight strikes them day after day. It is probably not the light of the sun, but rather the heat which does injury to these plants. Long before the engineer discovered that heat rays might be separated from light rays by interposing a water screen, these ferns were enjoying the beneficent activity of the ever-present clouds in absorbing the thermal portion of the solar radiation while transmitting a large proportion of its light.

In fact, the tree-fern lives under very nearly perfect conditions from the standpoint of a plant. There must be moderate uniform temperatures, abundance of soil moisture, high humidity, freedom from strong air currents, and a maximum amount

WALKING FERN WITH DROP OF WATER ON TIP.


The Silver Fern. The Golden Fern.

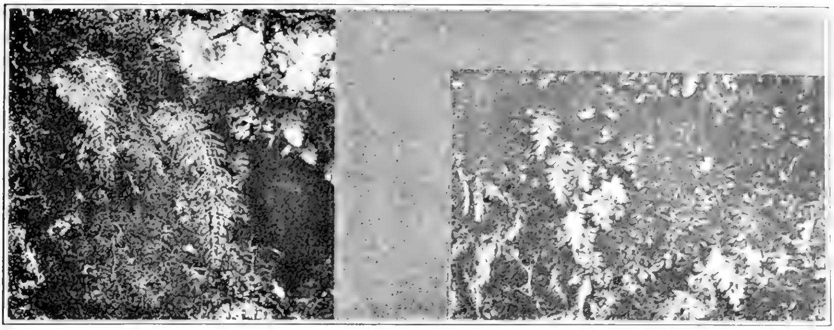



The Black Fern. Like the Wings of a Bird.

FERNS OF MANY FORMS AND COLORS.

of light. Only the mountain rain-forest of the tropics can afford this ideal combination of environmental factors. Here of all places is the paradise of ferns. Ferns carpet the floor of the forest and the walls of the steep-sided ravines. There are walking-ferns with the tips of their leaves projecting into a long beak, curled at the end. Water repeatedly falling collects in a drop on this little curl, and within this drop of water a bud develops. As this bud increases in size and weight, the leaf bends over, finally touching the ground where the new plant can start life independently.

Then there are black ferns, the backs of their leaves densely covered with black reproductive bodies, known as spores. There is the silver fern too, but the white color of the under surface of its frond is due to air within and among the minute hairs which grow there. A similar cause is responsible for the gilded appearance of the under side of the leaf of the golden fern. Some ferns are very harsh and form dense, almost im-



The most delicate.
Hymenophyllum polyanthos.

The smallest.
Hymenophyllum fucoides.

On a Moss-covered Log.
Trichomanes crispum.

Lacelike though sharp and harsh.
Trichomanes rigidum.

FILMY FERNS.

passable thickets; such are the hogferry, rambling fern and certain species of forked ferns. Others climb the trunks of trees, or perch on the branches. But the tree-fern, the aristocrat among them, stands head and shoulders above all its kinfolk, both in stature and in esthetic grandeur.

In the old world tree-ferns are distributed between 47° south and 32° north latitude; a few are found in the extreme southern portion of Japan. They are most abundant, however, in Australia and the Pacific Islands, though fairly numerous in Ceylon, Java and New Zealand. The starchy pith of some of the New Zealand species is used as food, or is fermented and shipped to India, where it is consumed as an intoxicating beverage called "Ruckschi." In the western hemisphere their range is more limited, from about 44° south to 25° north latitude. The Hawaiian Islands and the Antilles, the Andes and Central America have many forms, but they especially abound

FERNS OF MANY SIZES BY THE WAYSIDE.

on the island of Jamaica. Dr. Forrest Shreve has made a special study of climatic conditions in their habitat in Jamaica, and his interesting results were published by the Carnegie Institution of Washington in 1914.

Tree-ferns belong to a single family known as the Cyatheaceæ, of which there are about two hundred species. Not all of these species, however, are tree-ferns, but many have a horizontal stem, as do ordinary ferns. These two hundred species are grouped into four genera: *Cyathea, Alsophila, Dicksonia* and *Hemitelia.* Of the last-named genus the tallest is *Hemitelia Smithii,* growing in New Zealand to a height of less than twenty feet. *Cyathea* reaches its greatest development in Jamaica, where the stems of two species, *furfuracea* and *pubescens,* may measure more than forty feet. The maximum height of *Dicksonia* is attained in Australia, where *Dicksonia antarctica* is found at times to be at least sixty feet. In this same region grows the tallest of them all, *Alsophila excelsa,* which has been reported to lift its crown as much as eighty feet above the ground.

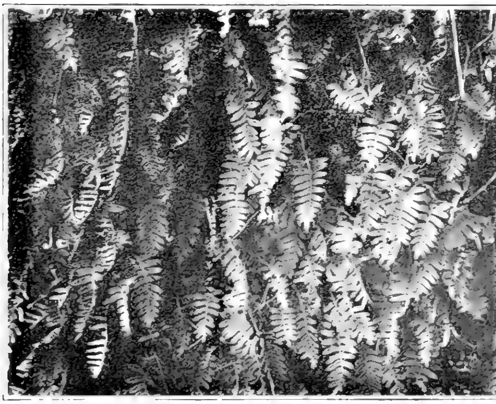
The stems of tree-ferns rarely branch. When they do, it is not a branching at right angles, but a dichotomous forking of the main stem, resulting in two crowns of leaves. In some species the leaves remain attached to the stem after they have died, completely hiding it. Usually, however, after the work of food-manufacture and spore-formation is finished the leaf breaks away, leaving a scar which may be a half inch or more in diameter. It is slightly oval and, like a cameo, elevated above the surface of the stem. Every leaf-scar has markings symmetrically arranged in some sort of pattern characteristic of the species. These markings are a series of pores or tubes through which water was carried upward to the leaves and food materials downward to the roots. In *Cyathea furfuracea* a circle of twenty of these ducts, equally spaced, lies just inside the margin of the leaf-scar. Within this circle is a smooth triangular area bounded by eight more pores, the apex of the triangle pointing downward.

These scars are arranged in seven longitudinal rows up and down the stem, slightly winding about it in a sort of loose spiral. This spiral is undoubtedly brought about by the torsion of the stem during growth, the rigidity of the stem being so great that it could not have been twisted after once being formed.

The area between the leaf-scars is covered with two kinds of structures: the ramentum and the roots. The former, characteristic of most ferns, consists of brown chaff-like scales an inch or more in length. They envelop the young leaves and roots, protecting them in their early stages. In all ferns the

The Smallest
Mixed with Spongy Lichens.

The Largest.
Pessopteris crassifolia.



Hanging over a Rocky Cliff.
Note fruit-dots on under surface.

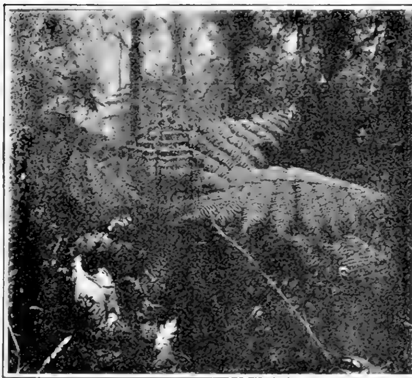
Rambling over the Rocks
amidst the Strawberry Leaves.

ENTIRE-LEAVED FERNS AND A *Polypodium*.

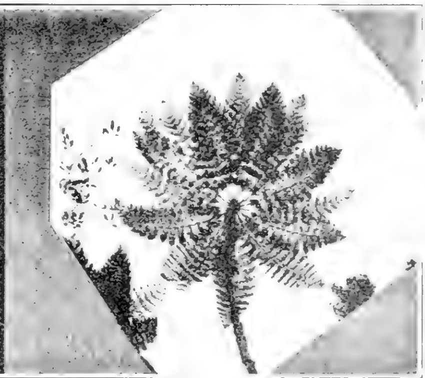
roots grow out between the leaf bases. The tree-fern thus has no tap root at the base of the stem, nor is the latter deeply sunken in the ground; hence, the necessity for tree-ferns to avoid windy places. The lower end of the stem is located almost on the top of the ground and the only means of support and anchorage are the numerous small roots which clothe its base. They are of about uniform diameter, rarely exceeding a fifth of an inch, and about twenty or thirty are produced around each leaf base. As the stem grows progressively upward, new roots are formed between the new leaf bases and grow down over the roots below, weaving in and out among them, forming

A Thicket of *Dicranopteris*.

Two Species of *Dicranopteris*, and a Bracken fern below.



A Thorny Vine. *Odontosorea jenmanni*.

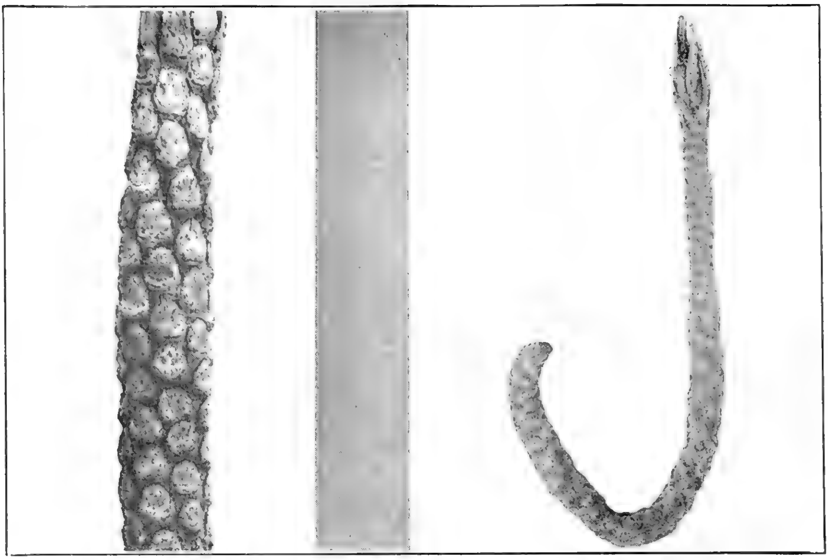


A *Dicranopteris pectinata*, showing the forking.

FORKED LEAVES AND RAMBLERS.

a compact entanglement, which at the base of the tree may become several inches thick.

This curious method of root development gives rise to some very interesting features in the life of this plant. The older roots, as well as the base of the stem, die, though they do not decay, so that the water for the leaves is carried by the younger roots for several feet above the ground on the outside instead of the inside of the stem. There is thus a greater amount of moisture required in the soil and in the air to compensate for the loss which is undoubtedly involved in the great exposure of the conductive tracts. On the other hand, this is an ingenious means of multiplying the number of conductive tubes, in the absence of cambium, to enlarge the stem. Furthermore, by the continued formation of new roots, the older ones may be dis-



Leaf Scars. Crooked by tumbling.

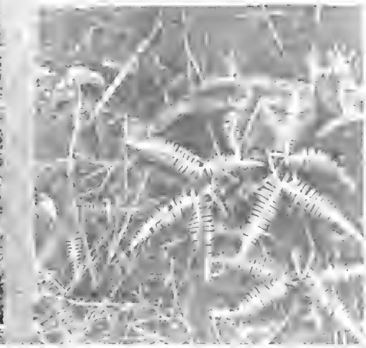
Rarely does it fork. The roots that clothe the base.

THE STEM OF THE TREE-FERN.

carded as soon as they cease to function without impairing the supply of water to the leaves. At the same time, the dead tissue of the roots and stem is utilized for support and for protection of the new roots.

Another beneficial feature of this mode of development of roots is shown when an accident has befallen the plant. Tree-ferns are especially liable to fall, both because of their slight anchorage and the great erosion due to the steepness of the slopes and the almost incessant rainfall. When a tree-fern falls

The Spreading Level Leaves.



The Silhouette against the clouded sky

The Monarch of the Jungle. Forty feet above the Soil.

THE CROWN OF THE TREE-FERNS.

upon its side, the new growth takes place in a vertical direction, forming an angle with the fallen portion. The new roots pass directly into the soil, leaving the prostrate portion of the stem entirely useless. The accompanying photograph shows a stem to which at least three such mishaps had occurred. When the writer found it, the base of the stem was projecting away from the soil, and only a few weak roots were keeping it from rolling still farther down the hillside.

The leaves of tree-ferns are always quite large. In *Alsophila pruniata* they frequently measure sixteen to eighteen feet, forming perfect arches beneath which one may walk without disturbing a single leaflet. The main axis of some of the fronds of a South American species are said to be as much as eighteen

THE ZONE ALONG THE MOUNTAIN'S SIDE.

meters, but this statement may be an exaggeration. The rachis bearing the leaflets may branch as much as six or seven times. Upon the under surface of these leaflets are borne the reproductive bodies, or sori. In *Cyathea* these are tiny smooth brown spheres within which are the numerous sporangia containing spores. In *Hemitelia* the sorus is cup-shaped, more than filled with sporangia. In *Dicksonia* it consists of two valves operating on a hinge. In *Alsophila* there is no covering for the sporangia which are simply grouped together in spherical clusters.

The young leaves are rolled in the bud in the form of a watch-spring, which is sometimes several inches in diameter. The inner coils are almost completely veiled from view by the chocolate-colored hair-like ramentum. The leaf gradually unrolls and each of the secondary branches is likewise seen to be coiled. Thus there comes to be a coil on the end of the main rachis and on each of its lateral branches. The growing tissue is within this coil and from it all parts of the leaf are produced. The strengthening tissue is the last to appear and, consequently, the coil hangs pendant from the tips of the leaf, giving the whole a drooping, wilted appearance. During the unrolling of the leaf the rachis is almost vertical, but as it grows older it bends more and more toward the horizontal. When this position is reached in most species the spores are shed, and then the leaf continues to bend downward, finally dropping off. This procedure is very similar to palm leaves, though the latter have no spores, and the leaves are formed singly. In the tree-fern there is a rosette of four or more passing through the series of changes simultaneously, and followed somewhat later by another set. Sometimes two or three sets may be seen in different stages at the same time.

It is a beautiful sight to behold, from the hillside above, these huge crowns with their delicate lacelike leaves, the leaflets all turgid and in a single plane. But the master picture is for him who looks, not earthward, but heavenward. As you walk through the jungle your eyes glance upward and behold a wonderful vision, a symmetrical silhouette of the enormous rosette against the soft background of the clouded sky. The fronds radiating from the apex of the stem like the points of a star present a distinctly artistic pattern. Go to the art institutes and museums of the world, you can not match this. This was modeled by a sculptor whose touch is infinitely more delicate than the clumsy fingers of the most skilled of human artists. Silently you marvel at the splendor, and with Browning,

> Look through Nature, up to Nature's God

THE DEVELOPMENT OF CONCEPTIONS OF PHOTOSYNTHESIS SINCE INGEN-HOUSZ

By H. A. SPOEHR

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THE various functions of a plant are so closely interdependent that it is impossible to study rationally any one activity without taking into consideration a number of others. It is constantly becoming more evident that imbibition, metabolism, growth, photosynthesis and transpiration are to a greater or less extent all interrelated, a study of the one requiring a knowledge of all the others. The physiological arrangements in vegetable organs are not obvious to the eye, they can be ascertained only by the application of a variety of methods, observational and experimental. These methods make use of a great number of different physical and chemical principles, the nature of which have been more or less definitely established, and in terms of which we now endeavor to interpret the actions of living things. The correlation of physical and chemical actions is of itself a difficult task, but when such actions have their seat of activity in living things, the task becomes tremendously difficult. Physiology is a great deal more than applied physics and chemistry. We must, however, rely upon these disciplines in order to form conceptions of the various vital phenomena, as operations of known causes. Thus these sciences have given us a vocabulary, while the true foundation of physiology will always be the direct observation of vital phenomena. The fundamental principles of the process of the utilization of the carbon dioxid of the air by the chlorophyllous leaf through the action of light, were established with almost no aid from physics and chemistry. Such an understanding of the phenomenon as we now possess has been possible only through the application of various physical and chemical facts. But photosynthesis is an exceedingly complex process, involving many factors and agents, all of which must be placed in proper relationship before a complete understanding can be hoped for.

It is not my purpose here to enter upon an elaborate historical discussion of the development of the ideas and theories relative to this subject. This is in itself a most fascinating and almost endless study, revealing often the most grotesque and

fanciful speculations of which the human mind has been capable. As in the history of every science, the carefully executed and exactly recorded experiments stand out as bright beacons to guide the workers in later generations. In no other way, perhaps, is the importance of reasoning only from careful experimentation and observation in order to gain light on the phenomena of nature brought home to one so clearly as by perusing the immensely prolix and speculative writings of most of the earlier workers. However, this fault is not entirely confined to our ancestors. In connecting the name of Ingen-Housz with the beginning of the development of photosynthesis, I do not mean to give all honor to one man. He stands as the representative of a group of highly-gifted investigators of a certain period and as is the case in all questions of this nature, each contributed a valuable portion to the whole. I purposely avoid discussion of the unfortunate and prolonged polemics which occurred at this time, a time-consuming study not altogether conducive to hero worship. However, from a plant physiological viewpoint and in the light of our present knowledge, the name of Ingen-Housz does stand out above his contemporaries as grasping the essentials of the cosmical function of plants. His little book of about 150 pages, "Experiments upon Vegetables," published 140 years ago, is one of the great classics of experimental plant physiology.

What then, briefly, was the status of the subject as found by Ingen-Housz and his contemporaries? Practically all of the work prior to this time was guided by the Aristotelian dictum that plants derive their nutrition from the soil. Against this mass of incongruous speculation there stand a few beautiful and classical observations. The great iatrochemist, van Helmont, endowed with extraordinary clearness of perception, denied the Aristotelian doctrine of the composition of organic matter and considered water the chief constituent thereof. His classical experiment is probably well known to all. In a pot he placed 200 pounds of thoroughly desiccated soil and planted therein a willow twig weighing 5 pounds. This was protected from dust and watered daily with rain-water. After five years the plant had enlarged greatly, and increased in weight by 164 pounds, while the earth, after desiccation, showed a loss of only 2 ounces. And almost three hundred years later Liebig was still fighting the humus theory of nutrition!

Probably the first to express the idea that the leaves are the organs which produce the substances necessary for the develop-

ment of the plant was the Italian, Malphigi, in the seventeenth century. He considered the chief function of the leaves to be the digestion of the nutrient sap rising from the roots. This process of digestion in the leaves was considered essential for the development of the plant, as was shown by the deleterious effect of removing the cotyledons (which he regarded as true leaves). He noticed, furthermore, that in the leaves are openings, "which," he says, "pour out either air or moisture," though it is quite evident that Malphigi did not recognize the other function of the stomata, namely, the absorption of gases. Grew in 1676 also pointed out the existence of stomata.

In considering the work on photosynthesis of this time, it must be borne in mind that the most confused and contradictory opinions prevailed as to the composition of the atmosphere. It is difficult to imagine the chaos which existed on a subject which now seems to us so simple. All the more remarkable are the observations of that brilliant investigator, Stephen Hales. He concluded that plants draw some part of their nourishment through their leaves from the atmosphere, and he was also the first to suggest the influence of light. A contemporary of Newton, Hales regarded light as a substance and asks "may not light which makes its way into the outer surfaces of leaves and flowers contribute much to the refining of substances in the plant?"

And finally there may be mentioned also the observations of Bonnet, who was the first to record the evolution of gas from submerged illuminated leaves, but he was not able to interpret properly his observations.

Priestley had noticed that plants confined in an atmosphere rich in fixed air (carbon dioxid) produced in the course of some time large quantities of dephlogisticated air (oxygen). Priestley explained the phenomena as caused by the growth of the plant and elaborated his discovery in relation to the cosmical function of vegetation. Schelle, working in Sweden, who had discovered oxygen simultaneously with Priestley, reported quite the opposite results; his plants produced fixed air (carbon dioxid) and he challenged the correctness of Priestley's results. On repeating his investigations, Priestley himself became confused through the irregular outcome of his experiments, looking always simply to the growth of the plant, and finally practically refuted his original statement.

Jean Ingen-Housz, an eminent physician, interested primarily in the influence of foul and pure air on the health of man, became enthused by the reports of the influence of oxygen

on living things. Schelle had shown that atmospheric air was composed of about[1] two parts of nitrogen, one part of oxygen and a small quantity of carbon dioxid. But the latter gas was also considered an element, though it was known that it was exhaled by animals, as was also its physiological property that it would not support life. Ingen-Housz was started on his investigations by Priestley's announcement that growing plants produce oxygen. He was, however, much more fortunate than Priestley in his experimentation. He soon saw that the mere growth of a plant had nothing to do with the purification of the air. His experiments are a masterpiece of manipulation and self-criticism. Step by step he approached the correct interpretation. It was the effect of the sunlight on the plant which produced the oxygen and this was due to the light, not the heat, which the sun radiates; and only in the light did the action take place, while the green leaves only were capable of this action. The carbon dioxid came from the atmosphere and the oxygen escaped through the stomata. High concentrations of CO_2 were toxic to the plant, and in the dark or even in the shade, not oxygen, but CO_2 was evolved. The contradictory results of Priestley and of Schelle were explained. Thus did Ingen-Housz grasp the very fundamentals of the process.

In 1784 Lavoisier established the composition of carbon dioxid and the nature of combustion. At this time the battle of opinions regarding these processes was at its height, and the value of Lavoisier's discovery was unheeded even by Ingen-Housz. But in his second publication he saw the matter clearly. The source of the oxygen was the carbon dioxid, the combustible matter of the plant was thus formed, van Helmont's experiment was explained, and the organism was seen to live by the burning of the material which it had itself formed. But there were also contributions from other workers; none of them, however, had the same clarity of vision and could distinguish between the two functions proceeding simultaneously, photosynthesis and respiration, nor made use of the modern conception of the composition of carbon dioxid. Sénébier executed extensive experiments and published voluminous elaborations. He showed how photosynthesis was affected by temperature, and by means of his well-known colored bell jars ascribed the chief action to the red rays of the spectrum. But the old Aristotelian dictum persisted; the roots were supposed to supply the leaves with solu-

[1] Black, Joseph, "Lectures on the Elements of Chemistry," 1st Am. ed. from last London ed., 1806, 2: 344.

tions of carbon dioxid. This was not definitely eradicated until the work of Moll and of Bousingault with pure water cultures.

As in all questions of this nature, so here it is also almost impossible to definitely establish who was the first to observe the utilization of carbon dioxid by the plant. Technically the honor probably belongs to Henry and Persival, though our present knowledge undoubtedly comes directly from Ingen-Housz and Sénébier. Although Ingen-Housz clearly described the phenomenon of CO_2 evolution both aerobically and anaerobically, it is surprising how long the erroneous conceptions regarding these processes persisted.

And finally to this period belongs the work of de Saussure. Though a contemporary of Ingen-Housz, Sénébier and Priestley, de Saussure attacked the problem a few years later. Perhaps nowhere else is there such a clear example of the tremendous change which had been wrought by the new chemistry of Lavoisier. From the style of thought and presentation, there might be a century between de Saussure and his contemporaries who had worked on this problem. De Saussure's conceptions of the composition of air, the nature of burning and the composition of water were clear and based upon definite experimentation. He worked entirely quantitatively; he asked a certain question and got a definite answer, and thus he established the quantitative relations of the phenomena which Ingen-Housz, Priestley, Sénébier and a few others had described, besides several new discoveries, more especially the rôle which water plays in the process of photosynthesis. De Saussure spoke a new language and followed a new system of thought. In fact, his work naturally would mark the beginning of a new era. But alas, it also marks the beginning of a rapid decline, both in investigation and in the presentation of existing knowledge on the whole subject of plant nutrition. A perusal of the textbooks as they appeared from about 1815, with a very few exceptions, reveal such unpardonable inaccuracy, indifference and simple ignorance as to be quite incomprehensible in view of the enormous importance of this phenomenon to human welfare. Most of the modern texts of plant physiology and physiological chemistry by no means escape this criticism. The beautiful experiments of the men just referred to were either forgotten or directly misinterpreted. The works of Dutrochet, Sachs and Pfeffer may be cited as the few great exceptions.

Aside from the discovery of certain details of the process of photosynthesis regarding the easily detectable products and the influence of certain exterior factors, the status of our knowledge is practically as de Saussure left it over 100 years ago!

What then are the causes of this lamentable stagnation, this apparent indifference to a branch of science which deals with a phenomenon upon which our very existence depends? It is not, I believe, to any one cause or condition that the situation can be attributed. We are not guilty of following an erroneous doctrine or system of thought. But the difficulty rather lies in the great complexity of the subject itself.

Among the botanists of the time the discoveries of Ingen-Housz and his contemporaries found no interest. This was at the time when Linné determined the course of botanical thought. There was at the time no such discipline as plant physiology; Hales, Ingen-Housz, Priestley, Sénébier, de Saussure were not botanists, but physicists and chemists. Here is an example of the deplorable results arising from the unfortunate sharp division of the various fields of science. Botany was not developing a symmetrical structure, but a highly lopsided one with attention restricted to the description and classification of plants. Cuvier, the great academician, one of the most illustrious men of that glorious age when France was truly the home of science, who did so much for botany, especially for its wide study and culture, utterly neglected the functional and nutritional phase. Nor did Humboldt, in spite of his unusual versatility and enormous influence in the world of science, affect the course of this subject beyond writing an introduction to the German translation of Ingen-Housz's work. The writings of Schleiden and of Liebig certainly did much to improve the conceptions of nutritional science of the day, but their efforts were entirely critical and not experimental, hence no real contributions resulted from their efforts; while such men as Mohl, Nageli, Hofmeister and Darwin were also following other lines of thought. The experiments of Bousingault do stand out clearly at this period. He finally demonstrated with his method of water culture the true source of carbon for the plant, as well as the fact that atmospheric nitrogen is not directly taken up by the plant.

Sachs through his studies of chlorophyll function awoke new interest in the subject. His work on the formation of starch, as well as that of Böhm on the effect of sugars on starch formation, has led to an extended elaboration of this phase of the subject. And finally Wm. Draper of New York conducted extensive investigations on the effect of different portions of the spectrum on the evolution of oxygen, the results of whose work have been verified and extended by the studies of Pfeffer. Most of the botanical contributions of the last thirty years have been largely confined to detailed studies along the courses outlined by these workers. It is not detracting from their value to say that

no new vistas have been opened nor original hypotheses formulated.

During the period just reviewed, all branches of science experienced development and revolution beyond all precedent in the history of thought. A discovery in one domain of science often exerted great influence over its allied or even distantly related sciences. We need but recall how the Newtonian gravitation formula affected not only astronomy and physics, but chemistry and physiology. During this time such fundamental conceptions as the conservation of energy, the undulatory theory of light, spectrum analysis, entropy and the primary laws of photochemical action were formulated, all of the most direct importance to the problem of photosynthesis. These great discoveries have even now found little application to our subject.

The most important aspect of the problem of photosynthesis is probably the energy relation. By virtue of this photochemical action we are kept alive, we derive all of our food, we keep warm, travel, and run our industries, by the use of fossil energy, coal. It is this question of energetics which in spite of some of the excellent attempts which have been made, has hardly been touched, and lies at the very center of the problem at least from a humanitarian viewpoint. As Boltzman pointed out in his classical paper on the second law of thermodynamics, the struggle for existence is essentially not a fight for the raw materials, which are abundant in earth, sky and sea, nor for the energies as such, but for the potential energies as in coal, sugar and meat.

It would seem that the plant itself is not very efficient in the utilization of this energy, and certainly our methods of determining the values have been anything but satisfactory. This is largely due to the number of variable factors entering into the experiment and calculation. The determinations of Puriewitsch may serve as a good example. The light was measured by means of a bolometer, and the amount of photosynthate or material synthesized was determined by the half-leaf method. The energy of this material was determined from the heat of combustion.

	Before Isolation	After Isolation
Area of half leaf	316.6 sq. cm.	316.8
Dry weight of half leaf	1.2494 g.	1.3952
Dry weight per sq. cm.	0.0039	0.0044
Heat of combustion of 1 g. dry weight	4300.21 g. cal.	4313.46 g. cal.
Heat of combustion per sq. cm.	16.770	18.978
Increase of heat of combustion after insolation per sq. cm.	2.208 g. cal.	
Total energy fall on leaf	361.03 g. cal.	
Energy used in assimilation	0.6 per cent.	

The values for the energy utilized vary greatly, from 0.6 per cent. to 5.0 per cent. with the same and different kinds of plants. One of the great difficulties has been that we do not yet know with what sort of system we are dealing. It is quite clear that it is not one simple chemical reaction, but a series into which various factors enter, and in some of which light plays the leading rôle. So that as the results indicate, these values are the merest approximations. In fact, the old question how does light act in effecting the reduction of carbon dioxid and water, seems almost as far from solution as ever. It is still an open question whether we are dealing with a so-called photo-catalytic action in which light only accelerates an irreversible process, in which case we cannot regard the energy of light as being stored in the transformed substance, or whether it is a true photochemical action. One great difficulty here has been that the physicists themselves have not been unanimous in accepting the theoretical principles of radiant energy and its relation to chemical action.

Recent conceptions of the nature of light and of chemical forces ought to find application to the processes involved in photosynthesis. It seems highly probable that the forces of chemical affinity are electrical in character, and matter may be regarded as a complex structure of small particles, the atoms, together with very much smaller particles called electrons. The number of electrons which accompany an atom to a large measure determine its chemical properties; valency under this conception depends upon the relative ability of the atoms to eject or attract electrons, and the chemical effects produced by light are due to the emission of electrons from some of the atoms of the illuminated substance. Each electron always has a negative charge of electricity and is therefore attracted towards all positive charges. Under certain conditions some substances lose electrons and acquire a positive charge. Thus there are a number of metals which when exposed to the rays of ultra-violet light take on a positive charge, and this has been traced to the emission of the negative electrons from the illuminated surface. The phenomenon is known as the photoelectric effect, and has been observed in a large number of substances, including a variety of dyes. There is considerable evidence for believing that the valency electrons which are the chemical bonds in molecules, are identical with the photoelectric electrons which can be liberated by the action of light. From this point of view, a photochemical change and a photoelectric change are of the same character, consisting primarily in the loss or displacement of an electron through the absorption of energy from a light

wave. It is not possible here to enter upon a discussion of the photochemical laws, but it seems quite certain that the first stage in any photochemical reaction consists essentially in either the partial or complete separation of negative electrons which are either emitted or attach themselves to other chemical groups or atoms. There takes place thus a rearrangement of the energy distribution in the system which, of course, involves chemical changes.

The phenomena of oxidation and reduction may be interpreted upon the same basis. Thus, for example, the oxidation of ferrous sulphate with bromine water may be represented:

$$2\overset{++}{\mathrm{Fe}} + 2\overset{=}{\mathrm{SO}}_4 + \overset{+}{\mathrm{Br}}_2 \rightarrow 2\overset{+++}{\mathrm{Fe}} + 2\overset{=}{\mathrm{SO}}_4 + 2\mathrm{Br}.$$

The ferrous salt is "oxidized" to a ferric salt and the bromine "reduced" to a bromine ion. It will be noticed that the "oxidation" (I purposely retain the old terminology) involves the passage of a positive charge to the ferrous ion, the bromine being the oxidizing agent, or the ferrous salt the reducing agent. There cannot be oxidation without corresponding reduction, and reduction consists essentially in the loss of a negative charge. Oxygen acts as an oxidizing agent because it has a great tendency to take away a negative charge from other substances and go over into electronegative oxygen of a compound, usually water. In photosynthesis the process is quite the reverse. If we assume that the action is empirically:

$$\mathrm{XCO_2} + \mathrm{XH_2O} \rightarrow (\mathrm{CH_2O})_x + \mathrm{XO_2},$$

water is oxidized and CO_2 is reduced presumably to carbohydrates and the negative charges are taken up by the carbon compounds. Thus photosynthesis must be accompanied by decided electrical disturbances and of a nature which are in a sense the reverse of those taking place in the oxidation of food material. This furnishes us with a point of attack and possible basis for the explanation of the electrical disturbances characteristic of living things. As yet no application has been made of these principles, though it is noteworthy that the atmosphere surrounding a leaf is ionized and Waller has described certain electrical disturbances in the leaf. These are apparently associated with the photosynthetic activity, for the action ceases on the removal of CO_2, and is not brought about by light which has been filtered through a green leaf.

McClelland and Fitzgerald have recently observed that

green leaves in the light of an aluminium arc exhibit a decided photoelectric discharge, as do also aqueous solutions of chlorophyll. I have tried to detect such an effect by the use of sunlight, but have never succeeded. It would seem that the electrons are emitted only under special conditions, and ordinarily are probably attached to the escaping oxygen or water vapor.

The application of physical conceptions and methods of experimentation as yet have not been applied to the study of photosynthesis with any high degree of success in penetrating to a clearer view of the process. This to a large measure has been due to the fact that our knowledge of the chemistry of the process has been so very fragmentary. The physical investigations have indicated that the process is apparently not a simple one, but dependent upon a number of variable factors. Physics employs essentially quantitative or mathematical forms of expression. But before quantitative terms can find expression, it is essential that at least a certain amount of qualitative knowledge is existent. We must know, at least, whether a proposition is affirmative or negative; some elements of the hypothesis must be established. Thus it was possible for de Saussure to apply quantitative methods to the discoveries of Ingen-Housz and Sénébier, but our qualitative knowledge has not progressed much beyond the discoveries of these men. Sachs elaborated the observations of Mohl on the starch grains and thereby introduced the subject of sugar chemistry into the process. It became then distinctly a chemical problem.

The course which the development of chemistry took was influenced by a number of factors. It is evident that science has progressed essentially by the efforts of a relatively few individual thinkers who set the minds of many working in certain directions, and that science, like social and political institutions, is not above the influence of fashions which have been followed by the majority, and often not altogether to the advantage of the broad development of knowledge. At the time of Liebig organic chemistry was devoted to the study of the chemistry of living things. But with the discovery of the constantly increasing number of carbon compounds and under the leadership of men like Victor Meyer, Kekulé, Hofmann and Baeyer, the primary interest was shifted to theoretical considerations of constitution and structure. Combined with this, the effect of the lure of the commercial application of synthetic products and the development of new processes, forced the study of chemistry of the phenomena of nature into second place. Physiological chemistry with relatively few disciples was de-

voted largely to animal investigation. And it is only within rather recent times that there has been a return to what might be termed general physiological chemistry with the plant studies in the decided minority.

Probably as a result of this state of affairs on the educational system, the contributions of the chemists to the problem of photosynthesis have not been of the thorough and profound nature which the subject demands. Most of the suggestions of the chemists concerning the course of the process have been purely hypothetical and speculative, exhibiting the most lamentable ignorance of the fundamental character of the process, and often with total disregard of the structure of the chlorophyllous cell and the properties of living matter. It is not surprising, therefore, that many botanists paid little attention to these efforts and few cooperative efforts were undertaken.

From the chemical viewpoint, the salient fact regarding the process of photosynthesis is that carbohydrates are the first products which accumulate in sufficient quantity for detection. It is by no means established in what manner these substances are formed, but as the formation of sugars has been found to accompany the process almost universally and the course of accumulation has been extensively studied, they have come to be regarded as the first visible products. The sugars then stand in the very center of the food economy of plants.

Before discussing the subject of the sugars themselves let us consider very briefly the manner in which these are supposed to be formed in the chlorophyllous cell. This portion of the problem has not advanced beyond the purely hypothetical stage, although it is very frequently treated as though the principle had been firmly established. The theory which has received the greatest recognition, and, it would seem, almost universal acceptance, is the formaldehyde theory. This hypothesis was formulated by Baeyer as a mere suggestion. During the fifty years since its appearance, this suggestion has become almost an axiom. It might be desirable, therefore, to examine briefly the evidence upon which this theory rests in order to determine whether its widespread acceptance is warranted by experimental proof.

In 1861 Butlerow had discovered that formaldehyde, in aqueous alkaline solution, condenses to an optically inactive syrup, possessing some of the properties of hexose sugars. Baeyer considered formaldehyde in aqueous solution to be $CH_2(OH)_2$, and the Butlerow condensation as simply one of water loss and condensation of six $CH_2(OH)_2$ molecules.

$$6CH_2(OH)_2 - 6H_2O \rightarrow COH \cdot (C(OH)H)4 \cdot CH_2OH.$$

Baeyer then suggested that this may be the way in which grape sugar is formed in the plant. The idea of the similarity of chlorophyll and hemoglobin was prevalent at the time; it seemed, therefore, likely that chlorophyll should also fix CO. The sunlight splits the CO_2 into CO and O, the oxygen escapes, and the carbon monoxide, held by the chlorophyll, is reduced to formaldehyde, $CO + H_2 \rightarrow COH_2$, which is then condensed to sugar. This is the substance of the Baeyer hypothesis, formulated without the support of experimental evidence. It was proposed as a possibility and received no further attention in the writings of its founder.

The fact which more than any other gave strength to this theory, and which is the underlying principle of the whole idea, was the discovery of Butlerow. This discovery was elaborated by O. Loew, who gave the name formose to the sugar mixture, and especially by Emil Fischer, who prepared therefrom some of the sugars found in nature.

The hypothesis has to a great extent directed the course of investigation of the chemical aspect of photosynthesis. The experiments have followed three different lines of argument:

(1) The reduction of carbon dioxid to formaldehyde by various chemical and photochemical means. (2) The detection of formaldehyde in illuminated green leaves. (3) The feeding of plants with formaldehyde as the only source of carbon.

All of these have yielded direct positive results, although it is impossible to give a description of the very numerous experiments. The main points at issue are, however, whether we are justified in applying the results of experiments carried out *in vitro* or under other abnormal conditions, to the living plant, and whether the conditions in the experiments simulate sufficiently those existent in the chlorophyllous cell to permit of valid deductions. In spite of the very numerous contributions which have been made to this special subject, a critical study of all the facts leads to the conclusion that it will require a great deal more experimental substantiation before this theory can serve as the basis for an explanation of the mode of sugar manufacture in the leaf.

Although Sachs had identified the formation of starch in the chloroplasts with the photosynthetic activity, it was later recognized by Meyer that many leaves never form starch. In the latter case there is an accumulation of cane sugar. Boehm then found that in either kind of leaf there was an accumulation of starch or sugar when the leaves were placed on solutions of glucose or fructose. The question has then naturally arisen as to

what is the first sugar formed in photosynthesis. This is, of course, an immensely important problem, as its solution would throw much light on the chemics of the photosynthetic process. As yet no definite solution has been gained, and the results are by no means concordant. The conclusions have been drawn largely from a consideration of the variation in amount of different sugars and from microchemical tests. The latter can not be considered sufficiently accurate to differentiate positively between various sugars. The following are the results of Brown and Morris with the garden Nasturtium, and serve as the best illustration. The values represent percentages of the dry weight.

Carbohydrate	Picked and Dried 5 A. M.	Picked 5 A. M. Kept Insolated in Water Until 5 P. M.	Picked and Dried 5 A. M.
Starch	1.23	3.91	4.59
Sucrose	4.65	8.85	3.86
Glucose	0.97	1.20	0.00
Fructose	2.99	6.44	0.39
Maltose	1.18	0.69	5.33
Total sugar	9.69	17.18	9.58

Carbohydrate	Picked and Dried at Once	Leaves Kept in Water in Dark for 24 Hours After Picking
Starch	3.69	2.98
Sucrose	9.98	3.49
Glucose	0.00	0.58
Fructose	1.41	3.46
Maltose	2.25	1.86
Total sugars	13.64	9.39

From these results Brown and Morris conclude that cane sugar is the first sugar formed in the leaf, and that it is a temporary reserve material which accumulates during active photosynthesis. When the cane sugar reaches a certain concentration, an excess is converted into starch. Prior to translocation, the cane sugar is inverted into glucose and fructose. The fact that leaves which are photosynthetically active all day contain no glucose or fructose is used by Brown and Morris as an argument that these can not be the first sugars formed. In the cut leaf insolated in water, translocation has presumably been stopped, and they point out that cane sugar and starch both increase greatly, but glucose very little. Fructose, the other hexose, it should be noted, however, increases decidedly.

One factor which has been overlooked in these considerations is the transformation of the various groups of sugars quite independent of the process of photosynthesis. This mutual

transformation is of the nature of a complex equilibrium with the monosaccharides as one extreme, and starch as the other, controlled, in all probability, by enzyme action. This equilibrium is affected by various influences, more particularly by the water content of the system and temperature. It is evident then that the amount, or proportion to the total of certain sugars present in the leaf after insolation, can not be taken as an indication of the rate at which these sugars are formed in the photosynthetic process, for under varying conditions of water content and temperature, such as occur in a leaf in the sunlight, there is a consequent shifting of the carbohydrate equilibrium, resulting in the accumulation of one or the removal of another group of sugars according to circumstances. Therefore, in a study of the first sugar formed in photosynthesis, these conditions (water content and temperature) either must be kept constant or, what is more feasible, the equilibrium under the particular circumstances must be established before any conclusions can be drawn as to the immediate source of any particular sugar.

The fleshy joints of some of the cacti have offered splendid material for studies of transformation of the sugars. These plants are capable of large variation in their water content, the joints can be removed from the plants and subjected to a variety of conditions without injury. Thus two sets of joints were kept at different temperatures in the dark for twenty days and then analyzed. The values are percentages of the dry material.

	28° C.	10–15° C.
Dry weight	33.0	33.6
Total sugars	5.72	6.21
Total polysaccharides	5.28	5.59
Hexoses and disaccarides	0.40	0.60
Total hexose sugars	2.17	2.38
Disaccharides	0.26	0.32
Hexoses	0.16	0.27
$\frac{\text{Total polysaccharides}}{\text{Total sugars}}$	.913	.900
$\frac{\text{Hexoses}}{\text{Hexose polysaccharides}}$	.0884	.147
$\frac{\text{Hexoses and disaccharides}}{\text{Total sugars}}$	.069	.0966

It is evident then that in general a low temperature tends to shift the equilibrium in the direction of the simpler sugars.

Similar relations hold for the effect of the water content. The table below gives the results of two sets of joints, one set (A) kept dry, the other (B) given water:

	A	B
Dry weight	22.80	17.70
Total sugars	18.84	18.58
Total polysaccharides	16.21	15.77
Hexoses and disaccharides	.56	.81
Total hesose sugars	8.43	7.81
Disaccharides	.30	.36
Hexoses	.26	.45
$\frac{\text{Total polysaccharides}}{\text{Total sugars}}$	.861	.849
$\frac{\text{Hexose}}{\text{Hexose polysaccharides}}$	.032	.063
$\frac{\text{Hexoses and disaccharides}}{\text{Total sugars}}$	.0297	.0436

Thus the water content of a leaf decidedly affects the nature of the sugars, and in such a manner that decreasing water content shifts the equilibrium in the direction of the more complex or more condensed sugars, while ample water brings about inversion or the formation of the simpler sugars. In the pentose series the action is of the same nature. It is a noteworthy fact that the water content does not seem to affect the rate of respiration as measured by CO_2 evolution.

Unfortunately in the results of Brown and Morris and the other workers who have investigated the problem of the first sugar, not sufficient data are given regarding leaf temperatures and water content. These factors when considered in the light of the results just given would materially affect the interpretation of the analyses.

The examples given here illustrate to some degree the complexity of the problem of photosynthesis. The enormous importance of this phenomenon to human welfare needs no elaboration. Progress undoubtedly lies in the fortunate cooperation and application of the methods and concepts of various branches of science; botany, physiology, chemistry and physics. The dangers lie in the over-application of physical and chemical theories based on restricted observation and acquaintance with the phenomenon itself.

MAN AND HIS NERVOUS SYSTEM IN THE WAR

BEING SOME REFLECTIONS UPON THE RELATION OF AN ORGANISM TO ITS ENVIRONMENT

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ADMIRAL SIR JOHN JELLICOE, in the dark months of the past year, advised his countrymen to look at a map, and, furthermore, to look at a large map if they wished to get a true perspective of the war. I would like to present a picture for inspection, and, furthermore, I would like to present a large picture, as I believe that in a large picture we may find comfort. In a large picture, some of the lines may be blurred and indistinct when examined microscopically, but the perspective is better. And when once we get a perspective, we may elaborate detailed portions of the picture to the limit of microscopic vision. The picture, to be sure, is, in part, drawn after the events have occurred, and to this extent now represents afterthought rather than forethought. But if I mistake not, some of the conditions which have given rise to trouble in the past will greatly outlast the war, and a recognition of the sources of evil in the past may help us in avoiding, or in coping with, the sources of evil in the future. Assuredly, man's mind is in need of comfort, and while one does not ordinarily look to the biologist for comfort in times of adversity or trial, I hope to be more successful than the officious gentlemen who called on Job.

Some, like Mr. Britling's son Hugh, have tired of the war at times and wished for stories of gods and heroes so that they might forget for the moment the horrors of the conflict. I have at times been one of them. But not until the news of the signing of the armistice arrived was I able to sit down and read with untroubled mind anything that did not have some more or less close connection with the war and the part which I was trying to fulfil in it. For those who may have felt as I did at times, but who still look forward with some anxiety to the formulation of the peace terms and the statement of the means adopted for curbing some of the vanities of human ambition for the future, I wish to show that the study of the effect of war and war conditions upon man is a biological study of the effects of

the environment upon organisms and that if the essential relations of biology to the life of man had been fully recognized this war might not have come. I wish to present a statement that I have worked out in my own mind in the terms of my chosen science, physiology. To be sure we are dealing with one species of organisms and not with organisms in general; and the environment bears the trade mark, "Made in Germany." But biology is essentially an inductive science, or group of closely related sciences, rather than a deductive science, and inferences drawn from a study of one group of organisms will fit somewhere in the general scheme of inductive thought when it is finally worked out. I will first map out the general field of physiology as it has been developed up to the present, and then show how the information now available may be applied to some of the problems of the war.

The Progress in Physiology in the Past Century

The Place of Physiology in Scientific Thought.—For the benefit of those who may vaguely wonder, as some of my friends have wondered at times, what physiology has to offer to general biological thought or to scientific thought as a whole, a brief statement of the progress of physiology during the past century may not be out of place. Merz[1] speaks of the conflict early in the past century between vitalism and the mechanistic conception of life processes as one of the fundamental phases in the development of physiology, and attributes a large share in the founding of physiology on the mechanistic basis to Johannes Müller. Merz quotes Emil Du Bois Reymond[2] as follows:

> The modern physiological school with Schwann at its head, has drawn the conclusions for which Müller had furnished the premises. It has herein been essentially aided by three achievements which Müller witnessed at an age when deeply-seated convictions are not easily abandoned. I mean first of all, Schleiden and Schwann's discovery, that bodies of both animals and plants are composed of structures which develop independently, though according to a common principle. This conception dispelled from the region of plant-life the idea of a governing entelechy, as Müller conceived it, and pointed from afar to the possibility of an explanation of these processes by means of the general properties of matter. I refer, secondly, to the more intimate knowledge of the action of nerves and muscles which began with Schwann's researches, in which he showed how the force of the muscle changes with its contraction. Investigations which were carried on with all the resources of modern physics regarding the phenomena of animal movements, gradually substituted for the mir-

[1] "A History of Thought in Europe during the Nineteenth Century," I., p. 217, Edinburgh and London, 1903.

[2] Reden, Vol. II., p. 219.

acles of the "vital forces" a molecular mechanism complicated, indeed, and likely to baffle our efforts for a long time to come, but intelligible, nevertheless as a mechanism. The third achievement to which I refer is the revival among us by Helmholtz and Mayer of the doctrine of the conservation of force. This cleared up the conception of force in general, and in particular supplied the key to a knowledge of the change of matter in plants and animals. By this an insight was gained into the truth that the power with which we move our limbs (as George Stephenson did those of his locomotive) is nothing more than sunlight transformed in the organism of the plant: that the highly oxygenated excrements of the animal organism produce this force during their combustion, and along with it the animal warmth, the "pneuma" of the ancients. In the daylight which through such knowledge penetrated into the chemical mechanisms of plants and animals, the pale spectre of a vital force could no more be seen. Liebig, indeed, who himself stood up so firmly for the chemical origin of animal heat and motive power, still retains an accompanying vital force. But this contradiction is probably to be traced to the circumstance that the celebrated chemist came late, and as it were from the outside, to the study of the phenomena of life. And even Wöhler still believes in a vital force, he who in his time did more than any one to disturb the vitalistic hypothesis through his artificial production of urea.

Merz later admits that the French physiologist Vicq-d'Azyr, who, by the way, was a professor in the Ecole veterinaire d'Alfort and a neuro-anatomist of considerable ability, had, earlier than Johannes Müller, clearly stated the mechanistic conception of life processes. Merz[3] quotes from Du Bois Reymond[4] this extract from Vicq-d'Azyr:

Quelqu' étonnantes qu'elles nous paraissent, ces fonctions (viz., dans les corps organisés) ne sont-elles pas des effets physiques plus ou moins composés dont nous devons examiner la nature par tous les moyens que nous fournissent l'observation et l'expérience, et non leur supposer des principes sur lesquels l'esprit se repose, et croit avoir tout fait lorsqu'il lui reste tout à faire.

One may remark in passing that, despite his recognition of the relation of the cell theory to the Aristotelio-Drieschian conception of an entelechy, Johannes Müller[5] still remained much of a vitalist. So deeply was the vitalistc theory ingrained in

[3] *Ibid.*, p. 219.

[4] Reden, Vol. II., p. 27.

[5] Although he himself (Müller) is truly regarded as the last of the vitalists—for he was a vitalist to the last—his successors were adherents of what has been very inadequately designated the mechanistic view of the phenomena of life. Burdon-Sanderson, J. S., *Nature*, 1893, XLVIII, p. 466.

Even after the discovery by Wöhler in 1828 of the possibility of producing synthetically such an organic substance as urea, such a universal mind as that of Johannes Müller was still clinging to the belief in the all-powerful force as the creator and harmonizer of the various mechanisms of the living body." Meltzer, S. J., *Science*, 1904, N. S., XIX., p. 18.

the minds of physiologists and others that Du Bois Reymond years afterward remarked that behind such terms as cell autonomy there lay concealed the thinly veiled specter of vitalism.

Merz's statement may appear insufficient to the physiologist, but I am merely quoting it to show just what impression physiology as a whole has made on the mind of a keen and diligent student of scientific thought in the nineteenth century. Compared with his statement on morphology, it is meager enough. One unfamiliar with the great names in physiology, and who did not look through the index for them would truly get an inadequate idea of the influence of physiology upon thought in the past century. Nor do the references to the physiological units of Herbert Spencer or to "physiological division of labor" really carry us much further into the place of physiology in scientific thought. For Milne-Edwards was an anatomist and comparative physiologist, and Herbert Spencer a philosopher. Their conceptions of processes or properties, however valuable they may have become in biological thought, can scarcely be claimed as the property of the workers in the technical laboratories of physiology. Howell[6] epitomized the situation by saying: "We must perhaps admit that the philosophical basis of physiology, its general principles and quantitative laws, have been borrowed in large part from other departments, and that the subject has not as yet fully repaid this indebtedness by contributions derived solely from its own resources." Nor does one find much mention of the relation of physiology to the other biological sciences in Verworn's article "Physiology" in the Encyclopædia Britannica. But if, as is generally alleged, physiology is one of the biological sciences, it must have some elements in common with them and hence some relation to the great questions of biology. It would seem permissible, therefore, to add something more on the place of physiology in scientific thought. We may first review briefly the progress of physiology, in order to get a background of fact upon which to base our conclusions, and then search particularly for those phases of the work which may serve to connect physiology with the great problems of biology in general. Those who are especially interested in the development of physiology should read also Professor Howell's address and those by Professor Burdon-Sanderson and Dr. Meltzer to which I have just referred. As will become apparent from what follows, the particular field of physiology has been the study of the individual and its internal conditions.

[6] "Problems of Physiology of the Present Time." Congress of Arts and Science, Universal Exposition, St. Louis, 1904, Vol. V., p. 1.

The Study of the Internal Organization of the Living Organism

The work in physiology during the past century, and one should add twenty-five years to cover the beginnings in the eighteenth century and the continuation in the twentieth, has been along the lines of the chemical organization and a nervous organization. I will not enter here into a discussion of the moot question whether the nervous mechanism may not be at bottom a chemical mechanism. Assuredly, the nervous mechanism has some chemical properties, but the methods of investigation of the two systems are at present sufficiently different in character to warrant us in retaining the term nervous organization for a time at least. While investigation of the two systems of organization has proceeded more or less together, the development of the knowledge of each may be considered separately. Other writers might not choose the same facts or the same names that I have chosen, but I have taken those things which seem adapted for bringing out the particular points I wish to emphasize.

The Chemical Organization of the Body

Lavoisier, toward the close of the eighteenth century, showed that the heat production by an animal in a given time was directly proportional to the amount of carbon dioxide produced in the same time. This result led to the discussion of the nature of the chemical processes in living matter. It was generally admitted that the production of heat in animals was the result of a process of slow combustion, and the idea of a catalytic agent and of catalytic reactions soon followed. We have come to recognize more and more clearly that many of the chemical reactions occurring in living matter are of the same general nature as the "slow" reactions of the laboratory of physical chemistry.[7]

The line of investigation started by Lavoisier had other results. His original experiment in animal calorimetry was repeated with greatly improved methods by Regnault and Rieset, Pettenkoffer and Voigt, Atwater and Benedict and others, until the original discrepancy of a few per cent. between Lavoisier's observed results and the calculated results has been reduced to a few tenths of one per cent. From these experiments, and van Helmont's earlier experiment[8] on the increase in weight of a tree, the modern study of metabolism has arisen. Biologists generally regard metabolism as one of the funda-

[7] Blackman, F. F., *Nature*, 1908, LXXVIII., p. 556.

[8] Foster, "Lectures on the History of Physiology," 1901, p. 133.

mental properties of living matter. Goodrich's statement[9] in 1912:

> The metabolic process in living matter draws in inorganic substance and force at one end, and parts with it at the other; it is inconceivable that these should, as it were, pass outside the boundaries of the physico-chemical world, out of range of the so-called physico-chemical laws, at one point to reenter them at another,

is a sufficiently close restatement of Vicq-d'Azyr's conclusion of more than a century before to justify the correctness of his physiological vision. That we do not yet know all the transformations of inorganic substance and force in the metabolic process is true. But to say that such transformations are not physico-chemical processes, as I have heard it said at various times, involves a peculiar mental operation which I am at a loss to understand. One might as well say that, because we can not explain the transmission of electricity along a wire—and I am not aware of any such explanation at present which is complete and wholly free from objection—such transmission is not a physico-chemical process. If vitalistic properties enter into metabolism at all, they can not consume more than a few tenths of one per cent. of the total energy involved in the process. To the other virtues of vitalism which Du Bois Reymond mentioned in his own humorous way, we must, therefore, add extreme economy of operation.

The artificial synthesis of many of the products at one time supposed to occur in living matter only, beginning with Wöhler's synthesis of urea in 1828, and extending through a long series of carbohydrates and even of polypeptids, is another series of achievements along the line of the chemical organization of the organism. Through the chemical study of the nature of the various compounds occurring in living matter, we have been able to extend our knowledge of the processes of metabolism in general, and of nutrition in particular.

The doctrine of the conservation of energy led to a new discussion of the position of life. Balfour Stewart[10] compares living matter to the class of machines whose distinguishing characteristic is their incalculability. He mentions also that "Joule, Carpenter and Mayer were at an early period aware of the restrictions under which animals were placed by the laws of energy, and in virtue of which the power of an animal, as far as energy is concerned, is not creative but directive."

Physiologists generally have considered this characteristic

[9] "The Evolution of Living Organisms," London and New York, p. 15.
[10] "The Conservation of Energy," New York, 1874, Chapter VI.

of incalculability in living matter under the head of irritability, and it has been recognized by biologists generally as one of the essential characteristics of living matter. It must be considered in any discussion of the internal organization of living organisms. Much misty terminology and vagueness of expression has clung about it, and the conception of irritability as Pfeffer formulated it has much of the element of vitalism in it. Blackman has expressed the hope that some of the implications of irritability will disappear from biology, and be superseded by a more modern statement in terms of chemical mechanics. As attention has been more and more focused upon it, the incalculability of deportment of living matter has been found to be little or no greater than that of high explosives in government storehouses, and one would have some hesitancy in attributing vital characteristics to explosives under recent diplomatic conditions. The term stimulus so often used in connection with irritability is another instance of a word which has no very definite meaning except a rather arbitrary one. It is my belief that the laws of chemical equilibrium are applicable, and will do much to clear up our idea on the subject. If, as there is now every reason to suppose is the case, the reactions in living matter are like other physico-chemical reactions, stimuli, which influence the reactions in living matter, are comparable to the conditions which influence ordinary physico-chemical reactions.

A discovery of considerable importance, as illustrating the action of a number of chemical substances in the body, was made by Bayliss and Starling in connection with the mechanism of eliciting secretion of the pancreas. These investigators found that when the acid contents of the stomach come into contact with the mucous membrane of the duodenum, a substance called secretin is formed in the mucous membrane. This substance secretin is absorbed by the blood and carried through the circulatory system to the pancreas where it excites the cells in such a way as to produce a secretion. Substances which, like secretin, are formed in one place and carried in the fluids of the body to another, there to elicit a response, are known as hormones or chemical messengers.

There have been other phases of work along the line of the chemical organization of organisms which would require too much space for a detailed consideration. One which seems to me significant is the determination of the various forms of starch grains and hemoglobin crystals by Reichert and Brown. These results tend to show that each species has its own peculiar physico-chemical constitution, that each organism has, in fact, a physico-chemical system of its own.

This work on the crystallography of the hemoglobins is an extension along another line of the work of Kossel on the chemical constitution of the protein molecule. According to Kossel, this consists of groups of aminoacids tied together, the nature of the acids and the number of each kind in the protein molecule depending upon the sort of protein selected for analysis. To a certain extent, the food value of any protein in animal nutrition depends upon the closeness of approximation of its qualitative and quantitative content of aminoacids to that of the tissues of the animal by which it is used for food.

Blackman, *loc. cit.*, in a most suggestive paper, has considered the chemical organization of the plant from the point of view of the application of the principles of chemical mechanics to the processes in living organisms. In the ten years that have elapsed since the publication of Blackman's address, the field of the application of the principles of chemical mechanics to the processes in living matter in general has been considerably extended.

It may be objected that we have never shown that the same principles cover the deportment of living and non-living matter, and the objection must be allowed. But neither do we know what principles cover the deportment of non-living matter in its entirety. Until we have gone farther in both fields, we have no rational basis for saying that living matter demands peculiar principles of its own. When it has been definitely shown that the principles of chemical mechanics, as they have been built up from the study of non-living matter, do not apply to living matter, or that no future principles which may be built up from the study of non-living matter will apply to living matter, we may be forced to take refuge in vitalism. But for the present, the free use of that old canon of logic known as William of Occam's razor[11]—the principle that the unnecessary supposition that things of a peculiar kind exist when the facts may be equally well explained on the supposition that no such things exist is unwarranted—should be freely applied in this connection.

But the chemical organization of the body, as has been stated, comprises but a part of the internal organization of the animal. We may now proceed to the consideration of the other phase, the nervous organization of the animal body.

The Nervous Mechanisms of Animals

The work on the nervous organization of the animal body has been done mostly on vertebrates, frogs, birds and mammals

[11] Entia non sunt multiplicandum praeter necessitatem. (Article "Razor," Century Dictionary.)

being chiefly used for experiment. Anatomical and pathological study has included the human nervous system as well. The influence of the Italian anatomist Rolando is reflected in the Rolandic area of the cerebral hemispheres, a term that still persists.

The French physiologists of the early part of the last century—Magendie, Le Gallois, Lorry, Desmoulins, Flourens and others—began or continued fundamental work on the organization of the central nervous system. Magendie published his text on physiology in 1816. So well were the chapters on the nervous system done that the Italian physiologist Luciani in 1893 wrote that he still found it a valuable and useful book. I can make the same statement in 1918. Magendie recognized the rôle of the central nervous system, not only in movement, but also in the maintenance of the attitudes of the body. He also stated that the division of the brain into its anatomical levels or segments such as cerebrum, cerebellum and the like was a purely artificial division so far as its physiology was concerned. In 1916 Luciani found occasion to emphasize the functional unity of the brain. Magendie also gave a statement of the mechanism of instincts which is so clear that I still regard it as one of our best.

Later in the century the discoveries in microscopy gave us definite ideas of the cellular structure of the nervous system. The accidental discovery of the Italian anatomist Golgi gave us a method of coating a nerve cell and all its processes with silver and enabled us to see clearly for the first time their exact form and extent. Anatomical and pathological studies have given us some knowledge of the relations of the fiber tracts in the brain and spinal cord. The anatomical phase of the subject is not yet complete and will not be for years to come.

The clinical observations of Broca on disorders of speech and of Hughlings Jackson on epileptic convulsions led to the early ideas of cerebral localization. The experimental results of Fritsch and Hitzig demonstrated that motor nerve fibers, excitation of which led to movements of particular groups of muscles, originated in definite regions of the cerebral cortex. Subsequent observations have shown that sensory fibers from particular sense organs have definitely localized end stations in particular regions of the cerebral cortex. There are still many unsettled questions in the field of cerebral localization, and much difference of opinion as to the degree or extent to which various functions rest upon an anatomically circumscribed basis in the cerebrum. Some would go so far as to deny

cerebral localization in some of its essential aspects. Personally, however, I regard the theory of cerebral localization, and of localization in general within the nervous system, as well established in its main outlines.

The idea of functional integration, or physiological integration, as Herbert Spencer called it, has an application in the nervous organization as well as in the chemical organization of the organism. On its nervous side, it has been developed by Sherrington as the integrative action of the nervous system. Aristotle remarked that there was nothing in the mind, except what had come in through the senses. This conception can, I believe, be carried over to the side of the motor responses as well as to the mental. There are conditions, apparently, under which motor cells may discharge impulses without the previous access to them of afferent impulses over fibers of other nerve cells; but it does not appear to be the normal biological procedure. Afferent impulses seem necessary for the proper control of motor responses, or, to paraphrase a statement of Edinger, afferent impulses seem necessary to make the motor responses biologically adequate. The afferent impulses must be summed up or integrated somewhere within the central system before a biologically adequate motor response can occur.

The ordinary motor response to afferent impulses may be called a reflex response. The essential condition is that an afferent impulse shall find its way into the central nervous system and thence be "reflected back" over a motor pathway to a muscle or gland at the periphery. In recent years, Pawloff has shown that a sound of a given pitch or a particular color, or other external agent which, by itself, will not bring about a reflex secretion of the salivary glands of a dog, may be sufficient to excite such a reflex secretion if employed for a time every day in association with the same external agent which will normally bring about a reflex of saliva. If, for instance, a dog is shown a square of blue paper every day at the same time it is shown food, which will by itself elicit a reflex flow of saliva, after the lapse of a few weeks, the sight of the blue paper alone is sufficient to elicit the reflex flow of saliva. Pawloff has applied the term "conditioned reflexes" to such responses. From my own experimental results and from data now in the literature, I have concluded that practically all reflexes are conditioned reflexes, since, as I see the problem, a definite group of afferent impulses from different peripheral sources is necessary if any reflex response is to be biologically adequate. A certain definite set of conditions is necessary, therefore, for the elicitation of a

definite reflex response. As may be gathered from these statements, I am inclined to extend the term reflexes to include a considerably larger group of phenomena than is covered by the older definition. On this point, I would sustain Loeb in his use of the term reflex in its wider meaning.

Beyond a certain point, the application of the general principles of chemical mechanics to the problems of the physiology of the central nervous system does not now seem possible. There has been, it is true, some change in the chemical composition of the nerves in the transition from frog to man. Certain protein substances which are coagulable at a temperature of 36° C. to 40° C.—a temperature below the ordinary body temperature of birds—appearing in the nerves of the frog are absent from the nerves of mammals and birds. But, in general terms, the same chemical foundation—the proteins as a group—is present, so far as we now know, in all nervous systems of vertebrates. Various other substances of a fatty nature, but all containing phosphorus or sulphur are also present in unmedullated nerve fibers, but we do not know either the exact nature of these substances in the nervous systems of various animal forms, nor how their variation affects the function of the nervous system at various levels in the evolutionary scale. The study of the metabolism of nerve cells and fibers is a chemical problem, and, to this extent, there is a chemical phase in the study of the nervous mechanism of the animal body. This chemical phase extends also to the study of disease in the nervous system, and through the work of Thudicum, Mott, Halliburton, Koch and others we have the beginnings of what we may hope will be an important phase of the study of the organization of the nervous system.

The study of the nature of the nerve impulse is also a chemical or a physical problem, or as now seems likely, a combination of the two.

The particular thing which characterizes the nervous system as a system is not its chemical organization, nor its rôle as a chemical mechanism, but its action as a coordinating or integrating mechanism. It is this integrative action which Sherrington has so luminously set forth in his writings. And it is by virtue of this integrative action in large part that man and the other animals express themselves by certain reactions arising in response to changes in the environment. Despite the objections that have been urged against it, and despite some obvious limitations, a modified anatomical basis seems the surest upon which to build at present. With, as I hope, a reali-

zation of its limitations, I may remark briefly upon the essential features of the method. Incidentally, the student of the scientific method may perhaps gain some idea of the diversity of the methods employed in physiology.[12]

We may regard the central nervous system as a physical rather than a chemical mechanism in the sense that, although some of the processes involved in the conduction of a nerve impulse and the excitation of a sensory ending, a central cell or an effector may be chemical, the relationships of afferent to efferent neurones are spatial rather than chemical, and our problem is not so much the problem of the nature of conduction and excitation as the problem of where the connection between incoming and outgoing impulses is made in the central system. The conduction paths traced out and the cell groups described by the anatomists afford a starting point, but they do not seem sufficient to answer all questions concerning functional relationships. The observation of the deportment of animals when some part of the central nervous system is lacking through disease or experiment and its comparison with the deportment of another animal of the same species when its nervous system and sense organs are intact is a necessary adjunct to purely anatomical study. The close and careful observation of the relation of the deportment of individuals of closely related species to slight differences in the organization of the nervous system has not been completed in most instances, but anatomical differences are observable in individuals of orders, genera or species less closely related. Observation of deportment of normal individuals, the modifications of deportment following disease or experimental procedures and anatomical description do not run unbroken parallel courses from the lowest animals to the highest; great gaps often exist in one or more lines of evidence, but some sort of a line may be traced from lowest to highest animals. Often, the three lines run parallel, and we see no apparent reason why, when all the gaps in all the lines of evidence are filled in by subsequent investigation, all should not run practically parallel throughout their courses.

The experimental method of the study of the function of the central nervous system is not particularly new. Some of the French experimenters of the early part of the last century have already been mentioned. But the method goes back even farther than this. Eckhard[13] refers to Pourfour du Petit's[14] re-

12 See Sherrington, "Physiology; Its Scope and Method," in "Lectures on the Method of Science," edited by T. B. Strong, Oxford, 1904.

13 Hermann's "Handbuch der Physiologie," Bd. 2, p. 106, Leipzig, 1874.

14 "Lettres d'un Médicin à un Médecin de ses amis," Namur, 1710.

search program of duplicating the various clinical manifestations resulting from disease of the brain in man by experimental procedures on animals. Needless to say, neither Petit nor those who have followed him even unto the present day have completed this program. But in the unhappy city and country in which Petit's program was first published, there has been inflicted upon the military and civilian population a series of experimental lesions of the nervous system by a race of supermen with bullet and shrapnel bomb, potato masher, grenade, bayonet, war club and high explosive, far transcending in variety and difficulty of execution the things which he contemplated doing on animals. And because of the employment of such methods, many of man's sufferings from the war and war conditions—deafness, blindness and shattered mentality—have been more noticeable in the present war than in other wars.[15]

The experimentalist, although attacking the same general problem as the anatomist—the organization of the central nervous system—nevertheless has a somewhat different point of view. His object is not so much the mere acquisition of knowledge of the architecture of the nervous system—the knowledge of the location and form of certain cell groups, and the course of certain fiber tracts—as getting at the place where and the manner in which certain forces originating at the periphery are summed up or integrated in the central system to produce a definite, orderly and biologically adequate motor response. The method of the experimental neurologist or student of the function of the nervous system is the method of physics rather than the observational method of pure anatomy. The term integration may carry one back to his college days and the class room in integral calculus. And, so far as I understand their point of view, psychologists look at the problem in much the same way that the experimentalist does. The incompleteness of our knowledge is still as great as that of the anatomist. And the persistence in physiology of words of uncertain signification, by which we sometimes delude ourselves that we have an explanation of certain processes beyond the point where knowledge really ceases, still affords too much warrant for those who try

[15] Mott, F. W., "The Effect of High Explosives on the Nervous System," *Lancet*, February, 1916, and following issues.

Wilson, J. Gordon, "The Effects of Heavy Shell Fire on the Ear," Harvey Lectures, New York, 1917–1918. To be published in 1919.

Smith, G. Elliot, and Pear, T. H., "Shell Shock and Its Lessons," 2d ed., London and New York, 1917.

Babinski, J., et Froment, J., "Hystérie, Pithiatisme et Troubles Nerveux d'ordre Réflexe." 2me ed., Paris, 1918.

to make the public believe that the words of uncertain meaning have a very clear and definite meaning. For only on some such basis can I understand the great vogue of the large and prosperous army of quacks who prey upon the unsuspecting or credulous public under the guise of faith healers, and the like.

The reader should bear clearly in mind that we do not now know either the chemical or the nervous organization in its entirety. And in attributing any particular response or kind of deportment to either kind of organization, we are using the terms to signify what it does, as determined by observation and experiment rather than what it is.

Space does not permit a further presentation of the great mass of anatomical and functional detail which has been gathered in the course of years of study of the nervous system. The general reader who desires to get further information on a system whose study will, I believe, become of more and more interest and importance to the public in the years to come will find the salient points of the anatomy and physiology in the article "Brain" in the Encyclopædia Britannica. Professor F. W. Mott's excellent little book on "Nature and Nurture in Mental Development"[16] embodies the results of long years of careful study of problems of heredity of mental disease and other phases of the nervous system of interest to those who are interested in the social aspects of insanity and criminality.

Two minor aspects of internal organization remain to be considered; first, the organization of the heart, and then the organization of the cell. The first is of great importance for the well being of the higher animals, and the second for general biology.

The Mechanism of Coordination of the Heart

The heart, to a certain degree, has an organization of its own. It is not a chemical organization in the sense that chemical substances must be carried or conveyed from one place to another in the body fluids, but a physical organization in that a wave of excitation is conducted over physical communications from one portion to another. It is now generally agreed that the impulses leading to the contraction of the various muscular groups of the heart originate in the Keith-Flack node (sino-auricular node) and are conducted to the muscles through the bundle of His (atrio-ventricular bundle) and the Purkinje substance. But whether the substance in the sino-auricular node in which the impulses originate is essentially nervous or muscular

[16] London and New York, 1914.

in character, or whether conduction in the atrio-ventricular bundle is over muscular or nervous tissue, or whether the Purkinje substance is nervous or more of the general nature of undifferentiated protoplasm are questions which, although subjects of controversy, do not particularly concern us here. The main point is that the organization of the heart is a physical organization approaching the general nervous organization more closely than the strictly chemical organization of the organism. The frequency of the heart beat may be changed by nervous and chemical influences.

The Organization of the Cell

The study of internal organization has extended also to the simplest organisms. Brücke (1861) called the cell the elementary organism and postulated an organization other than that represented by the visible structure. Whitman (1893) again insisted upon the importance of regarding the cell as an organism. Hofmeister some years later wrote on the chemical organization of the cell. But the study of the organization of the cell for many years has been predominantly a study of the chromatin material, principally from the point of view of the microscopist. This phase of the subject lies outside of the province of physiologist. The more recent work on the properties of cell membranes and the nature of colloids does, however, come within the realm of physiology, and is to be regarded as a part of our knowledge of the chemical organization of living matter in general. Its detailed discussion lies beyond the limits of this paper.

(*To be Continued*)

MODERN COMMENTARIES[1] ON HIPPOCRATES

By JONATHAN WRIGHT, M.D.

Prophecy and Prognosis

A RECENT historian[2] of thought has remarked, in a somewhat limited definition, that "the aim of scientific knowledge consists in the prediction of phenomena." Here is where the priest and physician of primitive man found for ages a common field of endeavor and a sense of reciprocal support and service. On the breaking asunder of these ties, which were cemented in mutual advantage by virtue of their reputation for the prediction of phenomena "in anticipation and consequent control of events," as well as by virtue of the necessity each had for the other in the struggle for existence among uncivilized savages, medicine at first clung to the processes and practices of the priestly class of which the doctors had formed a part. The aim of science as defined by Merz, it is true, is, in a limited sense, the prediction and control of events, but it has lost that meaning which had formerly been associated with the latter term—the absorption of power and riches. As it lost this meaning and thus essentially, it seems to me, changed its aim, medicine became a science rather than an art. The methods of the priestly class, of the mystic, of the fanatic, of the idealist, could no longer suffice for this new aim, which crept into medicine under a definition which we now clearly see was not definite enough. It still strove to predict events, but its aim became not only this; it became the ascertainment of truth as an end in itself and not simply "to control events." I do not mean to assert that religion also has not in its higher realization become a search for the truth, but in the sense we now give to the phrase it was a later development and it has never become an end in itself in its higher realization, because its ultimate aim is adoration or salvation and the aim of science does not go beyond the goal of truth.

[1] The translations of Francis Adams, "Hippocrates, Genuine Works," V, 1, New York, William Wood & Co., and E. Littré's, "Hippocrates, Oeuvres complètes," Paris, J.-B. Baillière, 1839–1861, 10 v., have been chiefly used and compared with Littré's Greek text.

[2] Merz, John Theodore, "A History of European Thought in the Nineteenth Century," Vol. IV., 1914.

In the treatises of Hippocrates in the work "On Ancient Medicine" and in that "On Airs, Waters and Places," we recognize an all-embracing catholicity of thought which carries as far beyond the domain of modern medicine and into that of many scientific problems with which we are to-day concerned. Upon these I have touched elsewhere in their connection with the history of medicine. I desire here to point out how prognosis as it has later developed in the evolution of the medical art was in the time of Hippocrates intimately interwoven with the practice of prophecy as applied in other mundane activities. The discussion as to whether the "Coacæ Prænotiones" is the derivation or the origin of the other books on prognosis—"The Prognostics" and "The Prorrhetics"—is not exceptionally important to the aspect of the subject which I wish to broach here, but it is not unimportant to take notice that three books have been preserved to us, whose titles indicate that their contents are taken up with the prevision of the future. When we read them we find indeed that they are largely devoted to the description and discussion of symptoms, but they are much more occupied with the question as to whether the patient is going to get well or not than with thoughts dwelling on the nature of the lesion and its cause. Pathology, in our view, had hardly arisen yet. They cultivated the study of those etiological factors in disease only remotely, in our sense, associated with the changes in the structure and functions of the tissues. They saw clearly many links in the chain of causation to which, unfortunately, we are all but oblivious. They were presbyopes, we are myopes.

In the closing paragraphs of the "Prognostics" Hippocrates warns us that we "should not complain that the name of each disease is not written down in this treatise for all those that are terminated in the intervals of time alluded to are distinguished by the same symptoms." The rendering of this clause is rather obscure in the translations both of Littré and of Adams, and I do not know that I have improved it by amendments, but the sense is that this is a work which has to do with prognosis, not diagnosis, derivable from the symptoms. Littré takes it that this refers only to acute cases, but as it evidently has to do in the text with cases of empyema—in which term we may probably include not only effusions into the pleural cavity but phthisis, I can not see how this remark is applicable. Neither can I understand why he looks upon it as a book of special pathology, even taking into consideration the difference in the signification of that term which prevailed fifty or

sixty years ago and now. I do not think we have anything to compare with it in modern medical literature. The idea of basing a book on the symptoms solely or chiefly for the purpose of arriving at a prognosis is foreign to our way of looking at medicine to-day.

I have elsewhere dwelt upon the danger the primitive doctor ran in ministering to the ills of wild men, in having more responsibility thrown on his shoulders than he could safely bear, in being credited with more knowledge and power than he in reality possessed. To secure the latter, in his close affiliation or even identity with the king and the priest, he claimed powers we call supernatural, and, as long as this close union of church and state and science existed, it had an invulnerability which it has never possessed since differentiation began. The first to be extruded from the entente was the doctor, then after many many thousands of years the priest, and now we are hunting for the blood of kings in their last lair.

In a previous essay[3] I have devoted more space to this very significant and very fortunate incident in the early history of the evolution of thought and I will only borrow from it the story of Livingstone. Livingstone,[4] one of the most fearless and one of the most humane of men, tells of a trying and perilous predicament in which he was placed at the death bed of an old and valued friend, an African king:

> Poor Sebituane . . . I saw his danger, but being a stranger, I feared to treat him medically, lest in the event of his death I should be blamed by his people. I mentioned this to one of his doctors, who said: "Your fear is prudent. This people would blame you."

There is a passage in the appendix to the treatise "On Regimen in Acute Disease," which is to the following effect in Littré's translation. In such and such conditions of the patient "never give hellebore, for it is to no purpose; and if anything happens to the patient, they will blame the medicine." Serious consequences perhaps were not so frequent for the physician in Greece in the unfortunate sequel to the treatment of a king, but the calamitous consequences are only a matter of degree for the doctor whenever and wherever the misfortune falls on him.

Adams, incidentally in the course of his remarks on this addendum to the "Regimen of Acute Diseases," says:

[3] *New York Medical Journal*, Feb. 24, 1917.

[4] Livingstone, David, "Missionary Troubles and Researches in South Africa," New York, 1868.

I myself—albeit but verging towards the decline of life—can well remember the time when a physician would have run the risk of being indicted for culpable homicide if he had ventured to bleed a patient in common fever; about twenty-five years ago venesection in fever, and in almost every disease, was the established order of the day; and now what shall I state as the general practise that has been sanctioned by the experience of the present generation? I can scarcely say, so variable has the practise in fever and in many other diseases become of late years.

One is apt to miss an important element in the development of medicine if one loses sight of the fact that when the public are informed as to the proper treatment of disease, to bleed or not to bleed, to expose the patient to freezing air or to protect him from it—the enlightened public in another generation or two may be an obstacle to the utilization of the "real truth" —not to bleed or to bleed.

At any rate old copies of popular information issued by boards of health should be destroyed after a few years. We are continually reminded of the caution necessary to secure a proper attitude of mind on the part of the friends as to the treatment of the case and that unfavorable results may not surprise them into a hostile state of mind toward the medical attendant. Should the aspect of the case give the latter a hint as to an approaching fatal issue "death may be anticipated, and it is well to announce it beforehand," we read in the "Prognostics."

I need not go back over what I have in several places elaborated in varying ways for varying opportunities of application in connection with the matter of the divorce of medicine from religion, but there is in this dissertation on the great value set on prognosis and prophecy another opportunity to introduce it in remarking how frequently we can pick out in the Hippocratic writings instances where he sounds a note of warning of the danger medical men run in the practice of their profession. At first thought it appears that the frequency of the intrusion of this serious matter in a discourse on the theory and practise of medicine is much greater than can be noted in modern medical literature. But though we may seek in vain for it in the stately volumes of medical science, as well as in the fugitive essays of the experimental activities and the inductive observations of more ephemeral modern literature, we must remember how specialized the latter has become. If we turn to the proper shelf we shall find the tomes on legal and forensic medicine, and in the special headlines of the weekly medical journals we will find them drawing our attention rather ostentatiously to space especially alloted to the very

problems the primitive doctor faced and to which Hippocrates alluded. It required the protecting shield of sacerdotalism in Egypt to protect the former and in Asia, in the story of Democedes we find in the pages of Herodotus medical slaves crouching in the dust before the king of kings, Cyrus the Great and Darius, or their writhing bodies impaled on the spears of his palace guards, and two thousand years later the relatives of the Turkish pasha whom Zerbi treated at Constantinople, tore the unfortunate doctor and his hapless son limb from limb because of the unexpected death of the patient. Prophecy and prognosis are in such a state of society or in anything approaching it very pressing and important departments of medical science. Hippocrates therefore is speaking pertinently when he says when death is anticipated "it is well to announce it beforehand."

The lay public has always been anxious to ascribe to the practioners powers which the wise among them are continually at pains to disclaim. The accounts of innumerable suits for malpractise which to-day fill the special columns of medical publications and the bulky volumes to which I have alluded remind us that Molière in echoing a jibe older than Petrarch or Pliny or Pindar was but speaking to the point in placing such words in his false doctor's mouth. Sganrelle's conception of the vantage ground on which he stood is a false one, quite consistent with the character of a médecin malgré lui, congratulating himself on the advantages of the doctor's calling, but blissfully unaware of its dangers. Molière was not speaking at all from the fundamental situation which underlies the relation of doctor and patient but in revealing the state of the public mind in the time of the *grand monarque,* he is uncovering for us in the study of the history of medicine an ever-lurking menace to the doctor. He reveals the attitude of the laity in an epoch of high civilization, looking with suspicion on the manner in which doctors employed the power of life and death they were believed by the common people to possess over those who submitted themselves to their ministrations. Sganarelle says:

> Que c'est le métier le meilleur de tous: car, soit qu'on fasse bien, ou soit qu'on fasse mal, on est toujours payé de même sorte. La mechante besogne ne retombe jamais sur notre dos; et nous taillons comme il nous plait sur l'étoffe ou nous travaillons. Un cordonnier, en faisant des souliers, ne saurait gater un morceau de cuir qu'il n'en payé les pots cassés; mais ici l'on peut gater un homme sans qu'il en coute rien. Les bevues ne sont point pour nous, et c'est toujours la faute de celui qui meurt. Enfin le bon de cette profession est qu'il y a parmi les morts une

honnetété, une discretion la plus grande du monde; et jamais on n'en voit se plaindre du médecin qui l'a tué.

Now I fancy this is the reason we find in ancient Greece prognosis taking the lead rather than diagnosis in the titles and thoughts of the authors of the treatises of the Hippocratic collection, for in free Greece exposed to the fury of the populace and out from beneath the shield of sacerdotalism, unprotected by king or court, it was well indeed to be a little "beforehand" in anticipating death and disaster. Thus prophecy was a very important element indeed in the equipment of the early Greek doctor and prognosis received an attention of which our courts of justice have deprived it to some extent.

If a modern physician stops for a moment to take an inventory of his own field of mental activity he will, I think, find that prognosis does not occupy a very large part of his thoughts in regard to his patients and still less those in regard to the diseases from which they suffer. It is true that in proportion as the practitioner is removed from centers of medical discussion and is confined by necessity or confines himself from choice almost entirely to the practical aspects of his avocation, in the sense of managing the patient as much as his disease, with eyes open to his own financial and social interests, he will be found making more shrewd guesses from the symptoms as to whether his patient is going to recover or die. It is not the lesion and its cause so much as the practical result of the condition in which he finds his patient. Adams likens him to the anxious pilot looking out for storm ahead and in this view of the importance of prophecy or prognosis, expressed or suppressed, he wonders why this branch of semeiology is no longer cultivated by the profession. The answer I think is quite evident to us. There are not so many storms ahead as there were in the days of Hippocrates, when medicine was being weaned from the nursing care of the temples of religion. The doctor found it more difficult than the priest to point out that the unexpected death of the patient intrusted to his care was due to the hand of God.

Now it is indisputable that less dangerous emotion was aroused in the breast of primitive man and to-day the shock is softened if the patients' friends can be prepared beforehand for a fatal issue. If they can be impressed with the seriousness and the danger of the condition, the prophecy of ultimate recovery may easily be so worded as to reflect credit on the doctor for a favorable result which he shrewdly judges is pretty liable to occur anyhow. So it appeared to Hippocrates

a most excellent thing for the physician to cultivate Prognosis; for by foreseeing and foretelling, in the presence of the sick, the present, the past and the future, and explaining the omissions which patients have been guilty of, he will be the more readily believed to be acquainted with the circumstances of the sick; so that men will have confidence to intrust themselves to such a physician. And he will manage the cure best who has foreseen what is to happen from the present state of matters. For it is impossible to make all the sick well; this, indeed, would have been better than to be able to foretell what is going to happen; but since men die, some even before calling the physician, from the violence of the disease, and some die immediately after calling him, having lived, perhaps, only one day or a little longer, and before the physician could bring his art to counteract the disease; it therefore becomes necessary to know the nature of such affections, how far they are above the powers of the constitution; and, moreover, if there be anything divine in the diseases, and to learn a foreknowledge of this also. Thus a man will be the more esteemed to be a good physician, for he will be the better able to treat those aright who can be saved, from having long anticipated everything; and by seeing and announcing beforehand those who will live and those who will die, he will thus escape censure.

I will not stop to inquire as to the reasons for receiving or rejecting the second book of the "Prorrhetics" as a genuine work of Hippocrates further than to remark it bears the imprint of some master hand. The question of its authorship is sufficiently discussed both by Littré and Adams, though it is found only in the edition of the former. The author, whoever it may be, continues in a train of comment entirely in keeping with the first paragraph I have just quoted from the "Prognostics"; indeed, the thought seems continuous. He says:

They quote the prophecies of doctors many, admirable, marvelous, such as I have never made myself nor heard any one else make. Here is one kind. A patient appears without any chance evident to the doctor who has cared for him or to other people; a second doctor comes along who proclaims that the patient will not succumb, but that he will lose his sight—

or it may be he will be lame of one arm—or that he may recover indeed but will have gangrene of one of his toes, or they have eaten something or drunk something or done something which is responsible for their conditions.

As for me I take note of the symptoms from which I may form some opinion as to who among my patients will recover and who will die, who will die or get well in a short time and who after a long time. I prescribe then for the lesions and indicate how each is to be regarded.

The opening phrases of these two books when taken together exhibit a common sense and a shrewdness and an appreciation of what is both prudent and seemly in the practitioner which at least in the simplicity with which it is set forth rises to the level of genius. He tries to explain how these seemingly

rash prophets arrive at their prognoses and how they elude discomfiture, but this does not interest us so much as another matter. This class of persons who incur the displeasure of the author by their propensity to "bluff" includes individuals who concern themselves not only with the prognoses of disease, but busy themselves with another sort of prophecy. Insurance offices were not yet opened to the venturesome man of business who still desires to cast an anchor to windward occasionally. Xenophon led an adventurous life and got into all sorts of unpleasant scrapes, and, evidently to keep out of them, he kept a prophet, like a medieval astrologer, by his side. It was a part of the prognostics of these prophets to whom Hippocrates refers to point out "to people whose occupation is business and venturesome enterprise, deaths for some, insanity for others, other diseases for others, prophesying in all these matters for the time ahead without ever making a mistake." He makes no reflections on the ethics of doctors who thus go around giving tips to business men as to people on whom they have to depend for carrying out their schemes. Perhaps he saw no harm in it at all. It has remained for modern life to capitalize prophecy and to back it with hard cash. Up in the top rooms of the skyscrapers along Broadway are medical men busy advising those who take chances on future events, who are going to die and when. They draw horoscopes and guarantee them. Xenophon's prophet drew the horoscopes, but it was a precarious job at best and without a guaranteed policy, issued for cash paid down in the form of the prophet's board and lodging. It soon became a neglected art, but it has been revived in London and Liverpool and New York in later times.

After Greek business men and soldiers of fortune gave up their prophets, the latter disappeared from history and do not emerge into prominence until the Arabian astrologers penetrated Christian precincts and we find them again at the elbow of the greedy, the lustful and the venturesome. In history, even, they appear in the Middle Ages as sinister figures, while among the novelists of the later romantic period they often appear as the arch villains of the plot. Scott made them so unpopular it seems almost like sacrilege to recognize in the medieval personage of the astrologer the connecting link between friends of Hippocrates and the medical directors of our life insurance companies.

When we apply ourselves to the texts themselves of the several books we find that the author by no means confines himself to discussing those appearances and internal symptoms of

the patient which can be used in forming an opinion as to whether the patient will die or live. Even where he does, as in the celebrated passage of "The Prognostics" on the facies of death, he describes appearances so striking that it scarcely requires the education of a medical man to discern in them the death agony. It is, however, the phenomenon itself which confronts the student when he engages first in the study of medicine. This is the condition he is expected to avert or whose onset he is to strive to delay in his future practise. It is in fact the central point in his field of interest. This state is the one which forms an excuse for many things he must insist upon in the regimen of the patient, this is the state to avoid which men will obey him and pay him eagerly all he asks. Despite its obvious nature then it finds its proper place as the first instruction the reader receives in studying the art of prophecy. It belongs in the category of prognostics as directly bearing upon it, but immediately we find the discourse wanders off into paths which quickly disclose to us the vistas of the practise of medicine as an art resting upon observations capable of apprehension by senses trained by their exercise. Prognosis *is* the practise of medicine for the wary Greek doctor. He wants to know not for the joy of knowing in itself, but for his behoof in making his way in the world and avoiding disaster. The title pages of these books therefore bear on their face evidence of the way the old Greek doctor looked on his profession. I think we are near the truth and not over-presumptuous in declaring that is not the typical attitude of the best part of the profession to-day. It is *not* now the first thing which occurs to the modern doctor as he enters on his profession or on his duties in attendance on the sick that "by seeing and announcing beforehand those who will live and those who will die he will thus escape censure."

I may thus be seeming to cast aspersions on the ethical nature of Greek ideals from a very singular elevation for the purpose—the solicitude of the doctor for his patient's future, the desire to soften the blow to the friends by preparing them for the worst. Surely in this day of altruism we have every reason to look upon such motives with approval. In the Spencerian philosophy we were taught how such altruistic sentiments arise from self interest, how sympathy and compassion arise from the inward reflection that the pain may be our own some day, this feeling growing in intensity to the point of actually feeling the pain and sorrows of others as our own in some sensitive natures. However indisposed we may be to explain

away all generous sentiments in our nature in this way, history plainly points out to us that this appreciation of the importance of prognosis on the part of the Hippocratic writers arose not so much from the disinterested impulses of nascent humanitarianism as from a knowledge of the consequences likely to follow from the resentment of friends and relatives who inherited the primitive idea that the issues of life and death are in the hands of the doctor himself.

If we turn to scan the actual words of this famous sentence on the facies of death, "*a sharp nose, hollow eyes, collapsed temples; the ears cold, contracted, and their lobes turned out; the skin about the forehead being rough, distended and parched; the color of the whole face being green, black, livid or lead-colored,*" we get a picture which has become classical in many literatures. Lucretius threw it into Latin verse and Celsus into Latin prose. Shakespeare's striking description of Falstaff's death-bed in words of Dame Quickly is also referred to by Adams:

> For after I saw him fumble with the sheets, and play with flowers, and smile upon his fingers' ends, I knew there was but one way: for his nose was as sharp as a pin, and he babbled o' green fields.—So he bade me lay more clothes on his feet: I put my hand into the bed and felt them, and they were as cold as any stone, etc. (Henry V., ii, 3).

Having quoted this familiar passage, Adams incidentally says in a footnote that he can not forbear to remark "that it appears to be rather out of character to make the wandering mind of a London debauchee dwell upon images of green fields." He thinks when such a person comes to die, his imagination would dwell rather on bawdy houses and drinking taverns. The old villain may well once have been a country lad attracted by the lights of the great town. The memory of age and the dreams of senility are those concerned with the scenes of our youth and he may well have "babbled of green fields" which wine, women and song had banished from the years which had intervened. Dame Quickly would hardly have noticed it if he had babbled of the lechery and drink of taverns. An incapacity to perceive wherein lies the genius of Shakespeare is not a very good equipment for the study of Hippocrates and a closer parallel to Shakespeare's description of the death of Falstaff can be found in another passage[5] in the Hippocratic writings, as I have elsewhere pointed out.

Notwithstanding the graphic realistic and impressive nature of the phrase in the "Prognostics" on the facies of death,

[5] "Epidemics," III., Case XV.

Hippocrates begins at once, in the same clause, to modify it, the earmark also of his genius, the incapacity not to realize that every phenomenon has a twofold aspect at least—that there are two sides of the shield to be inspected despite the neat thing he had said. Some of the symptoms may perhaps warrant a different prognosis. Perhaps the patient has slept badly, suffered long for food when first seen and this has put on him the impress of death. It is perhaps better to wait a day or two and see if the picture persists, or perhaps the patient has suffered two or three days from an attack of cholera. These cautious doubts flit through the mind of the careful practitioner and make him suspicious of his smartness at epigram: but after all —"all these are bad and fatal symptoms" and usually "death is close at hand." This is the difference between prophecy and prognosis. This is the difference, almost antipodal, between a prophet and a man of science, so wide apart have they grown who were once brothers. Hippocrates did not belong in the prophet class.

THE COMMERCIAL CONTROL OF THE MINERAL RESOURCES OF THE WORLD: ITS POLITICAL SIGNIFICANCE

By J. E. SPURR

OUR modern civilization and progress is largely a matter of more powerful and finer tools wherewith to control more and more the forces of nature and direct them toward advancing human comfort, convenience and power. These tools are constructed mainly from the metallic elements and minerals in the earth's crust. Breaking away from the use of wood and stone, hardly more than a hundred years ago, coal and iron made possible the railroad, the steamboat, steel bridges, ships, tunnels and canals, with the consequent beginning of the uniting of the peoples of the civilized world into a commonwealth. Nations became powerful as they possessed, or had free access to, coal and iron. Next with the development of electricity, copper became essential; by this means the telegraph, the telephone, the transmission line for power plants were made possible, and the substitution of hydro-electric power for steam. With the development of steel, more powerful materials became possible through alloys of steel with rarer metals, such as nickel, chromium, vanadium, tungsten, molybdenum and these latter became each in its way increasingly important. With the invention of the gasoline engine the oil concentrations in the crust came to rival in importance the coal fields, for thus was made possible the automobile and the airplane.

The races of men cover the land of the globe, save where the cold is too intense, at the poles; and also save where fresh water is scanty or lacking, for without water there can be, according to the terrestrial plan, no life, whether animal or vegetable. Everywhere else, in all lands, vegetable foods which feed the race may be grown. Wheat encircles the earth, in both hemispheres.

But the metallic elements which are found throughout the earth's crust are segregated or consolidated so as to be easily won by man in special restricted areas, not defined by latitude or longitude. Nor can such ores be transplanted or made by

human ingenuity to develop in spots where they do not exist. The culture of corn, potatoes and tobacco may be carried from America to Europe, and the breeding of horses from Europe to America, and thus original economic advantages may be obliterated, but not so with the mineral kingdom.

The occurrence or lack of these mineral concentrations in the lands occupied by a race constitutes, therefore, under the present system, one of the most fundamental and unalterable advantages or drawbacks to progress. The race possessing the fullest complement of these metals, in quantity, tends to increase most in power. The race that has them not, or not in due proportion, must, if it is to keep pace, obtain them, either by conquest or by trade, or both. The struggle for the borderlands between France and Germany, including Alsace-Lorraine, was a struggle for coal and iron.

The natural boundaries for autonomous states are those of race, tongue and geography; but the extent and forms of empires, and of their tentacles have been and will be determined by natural resources, chief among which are the fullest complement of the metals; and so it will remain until the world-federation, with free trade by sea and land.

Probably no nation has seen this so clearly as Germany. She had to, being relatively poor in natural resources.

Of all great nations (save, perhaps, the old Russian Empire) the United States has within its boundaries the greatest mineral wealth; and perhaps least of all great nations has realized its political significance. The United States possesses vast iron, coal and oil reserves; the richest copper districts of the world so far developed (probably only South America will rival them) and adequate lead and zinc deposits. Hence in large measure the rapid rise of the United States to power and wealth; hence her fitness for leading the world in civilization. She has the sinews of war, of peace and of growth.

Two elements of weakness in this respect present themselves. First, the lack of full development of internal resources, because in many instances it has been easier to trade than to develop. This defect the present war has in part remedied; and we should look to it that it is studiously remedied in the future. Germany possessed (before she lost Alsace-Lorraine) the only large resources of mineral potash in the world, and therefore deemed herself in a position to dictate to other nations and exact supplies of other raw materials, such as copper, rubber and cotton, which she must have. Nevertheless, we have vast stores of potash, especially in our silicate rocks,

which stores we have slowly developed under the stimulus of high war prices; and it seems entirely probable that we can, if we wish, supply ourselves entirely from domestic sources. Second, there are mineral resources in which our country is poor or lacking. Natural supplies of tin and platinum, for example, are practically wanting.

The possession of great resources by a country is not final as an advantage; for in the end it is not political but *commercial* control which gives rise to power, wealth and the growth of individual civilizations. Small nations and even lone cities have become powerful and dominant in proportion as they spread their web of commercial control over wider and wider areas. The old example of Phœnicia will come to mind, and later and more especially, Venice, and still later the Free Cities of Germany. The cramped islands of Britain drew the inhabitants to the sea, to voyaging and trading, with the consequent growth of a great empire and the attendant necessity of becoming mistress of the seas. Holland at one time furnished a similar example, as well as Spain, and even Portugal.

As the power of these great commercial nations, as well as their commerce itself, depends upon their fleets, so it is great naval battles that have in many cases signalized the fall of great world powers. The defeat of the Armada ended the control of the seas for Spain; the sweeping from the seas of Van Tromp's fleet for Holland; and by these and other naval victories Great Britain achieved her world predominance, which she can maintain in no other way than by her present naval policy.

Many of us have wondered what Germany meant by the "freedom of the seas." What else than relief from the naval control of Great Britain? Freed from this, the German navy would soon have strengthened and extended her overseas empire. The freedom of the seas can mean little else than that Britain shall so equalize her navy with that of other great powers that the navy of each of these shall have as equally impressive an influence (on minor as well as upon major peoples) as has that of England. We ourselves know well the valuable regulative power of a show of battleships and perhaps a landing of marines. "All very well," reflects Britain, "but how shall we police our world-wide empire against these very peers and commercial rivals of Britain unless our navy is preponderant; and what other nation has such a scattered empire to guard?" In truth, the control of the sea-lanes to Canada, India and Australia, is to Britain what the control of our transat-

lantic railways and of the Panama Canal is to the United States.

The commercial control of mineral and other natural resources is normally followed by political control. Spain sent expeditions to Mexico for gold and the Conquest was the result; much as in modern times, the English adventured in South Africa for gold and diamonds, with the consequent disturbances which ended in a war of conquest. To this day, as the underlying cause of great political events, careful scrutiny will often discern the necessity for minerals. The rôle of Mexico's mineral resources, especially oil, in her recent tempestuous history has yet to be unearthed from the secret archives and made clear.

Commercial control may be secured by political control, or may exist independently of it. We imagine that because the United States possesses great mineral wealth, she is, therefore, in a position to dictate to other nations, to withhold or supply. Does this follow in the case of China or India? On the contrary, it becomes a source of weakness unless coupled with commercial control. Where commercial control lies outside of China or India, the people pass under foreign domination along with the natural resources of their countries. It was with great good judgment that the Mormons hunted away the prospectors from Utah and forbade mining, knowing that the powers of the Mormon State would fall when mineral wealth was developed.

We fail to realize the quiet, incessant and invisible power of commercial control, working intricately and efficiently in a thousand ways, often almost, or quite, beyond the control of governments. In times of war a nation may set up partly successful barriers between its wealth and the grasping hands of other peoples; in times of peace there may more easily develop, unfettered, vast commercial empires whose boundaries do not by any means coincide with the political empires, and which possess great power, and shape the course of history.

What are we going to do about it? The first thing to do is to understand the facts and the essential elements of the problem. We must make a preliminary survey of the world to see, separately, where each of the essential metals is segregated into workable and valuable fields. Incidentally, we will note in what geographic boundaries and under what governments these great deposits lie. Next we must see who really owns them, what companies, where incorporated, and how controlled; and who owns the stock. But that is not all, nor most important. The key to commercial control lies not in the nationality of the stockholders, but in the nationality of the *capital* behind the

enterprises. This is not always easy to find out, but it must be charted as accurately as possible.

For us, one of the principal lessons of such a study will be that the United States Government must protect and encourage the investment of American capital in mineral wealth. (I write only from the standpoint of the study of ores.) It must do this in the United States, else we shall have our resources dominated commercially by foreign capital, close upon the heels of which normally follows foreign political influence and guidance. We must do it in minor countries which look to us for support, especially the minor American republics which we have long defended from European and Asiatic aggression and domination. The Monroe Doctrine, if held to, must be applied to commercial as well as political control. Germany at the outbreak of the World War had gone far toward establishing outposts of her commercial empire in certain parts of South America, which were fast becoming parts of her empire politically. Her progress would probably have been consummated had she not brought on the war; indeed, she was in a fair way to have established a commercial outpost in the United States, which would have affected the political control of our own country.

Commercial strength lies in the combination of capital, and only by recognizing and encouraging combinations of American capital engaged in mining can the well-organized foreign combinations of capital be offset and checkmated. The government should see to it that such companies are loyal and American, for loyalty in commerce is as important as loyalty in politics, and these companies the government should guide and control, in proportion as their size and influence increases, considering them as they grow, to merge gradually into what may be considered essentially public utility companies, to serve public uses, just as the railroads have been considered to be; and a full understanding and alliance should be made with such mining companies, who should understand the need and right of government direction. Herein—in the power and science of capital—lies much of the future of history, only it must be directed and handled for the common good. If we do not use this science of capital, we shall be easily outdistanced by more highly organized nations.

It is, perhaps, not too much to say that some economic or commercial reason lies behind nearly every political tendency and event, the sum total of which makes up history. I do not refer exclusively to the influence of capital. It may be the influence of labor or of the great mass of consumers. Most potent

will be this impulse where the influencing interests are best organized, and it is of course for this reason that the combinations of capital, no matter how justly they operate, are so powerful. The present stage of the world is the stage of organization and combination, and there have developed, in all advanced countries, very strong associations of capital interested in or even controlling certain industries the world over. It is idle to think it is possible to break up these combinations of business which like combinations of governments must, in the necessary course of evolution, grow stronger. It is, therefore, essential to study these forces in order that they may be coördinated and controlled. The remedy for the consumer and the laborer, against anything but benefits from such organized efficiency, lies in their exercising over it, through their governments, the control necessary to safeguard their position and to better it.

Modern invention, increased facility of communication, and modern time-saving and distance-eliminating discoveries, have led inevitably toward both commercial and governmental combinations. The progress from the prominence of state government in the United States through the strong federal control system, the constant accretion of territory and spheres of influence, and finally the plan of the world-combination of government, was the result of the same inventions which led commerce in all countries to gather in larger and larger pools, which finally became national and are now international.

A single example (among many available) of the problems of political and commercial control of minerals may be briefly cited. Petroleum will apparently be to the future what coal has been to the past—predominant in importance on the land, in the air and on the water—through the automobile and tractor, the airship and the modern petroleum-burning steamship, which apparently will largely supersede the coal burner. The control of petroleum production, and especially of strategic oil bunkering, will control the seas and commerce, in the interest, if need be, of the controlling nationality. Some extracts from an unpublished article by John D. Northrup, oil specialist of the U. S. Geological Survey, will illustrate this problem:

Position of the Leading Powers

United States:

With respect to developments expected in the petroleum industry, within the next decade, the position of the United States, thanks to the enterprise and foresightedness of financial interests of domestic origin, is apparently strong. United States interests are practically supreme in the

commercial control of the petroleum resources of the Western Hemisphere, dominating the petroleum industry in the United States, Canada, Mexico and Peru, holding substantial interests in Trinidad and Venezuela and in the prospective petroliferous areas in Central America and Colombia. Its only competitors are British and British-Dutch interests, which control the petroleum situation in Trinidad and are not only strongly intrenched in the United States, Mexico and Venezuela, but are aggressively seeking to enlarge their holdings in those countries and to gain footholds elsewhere. Unless the United States adopts measures to limit the aggressions of foreign capital in this country, such as federal operation of the trunk pipelines, and adopts either a firm forward-looking governmental policy toward the protection of investments of its citizens in petroleum properties in other countries, particularly Latin American countries, or adopts the more radical but amply justified policy of direct governmental participation in petroleum developments in other countries, it may witness its commercial supremacy in petroleum affairs wane and disappear, while it is yet the largest political contributor to the world's supply of petroleum.

Great Britain:

British and British-Dutch interests easily dominate the petroleum situation in the Eastern Hemisphere by domination of the petroleum industries of Russia, India and the Netherlands East Indies. The strength cf Great Britain's present position in the World's petroleum affairs lies in a strong governmental policy in the matter and in the wide scope of British petroleum investments, embracing practically every country of which petroleum is an important product and nearly every country of which it is a product of potential importance.

France:

Since control of the petroleum interests of the Rothschilds passed into the hands of the Royal Dutch-Shell Syndicate (British-Dutch), the influence of French finances in petroleum affairs has been negligible, outside Galicia and Italy, where its influence was not great. At the termination of the war French capital will undoubtedly participate in efforts to determine the petroleum capacity of the Barbary states, French dependencies, but that it will be appreciably involved in organized efforts to control the world situation with respect to petroleum is not anticipated.

Japan:

Japanese investments in the world's petroleum industry have not yet attained significant proportions outside Japan itself, though the Japanese government is officially alive to the importance of Japanese investments in petroleum properties in Mexico, particularly Lower California and Sonora, China, and undoubtedly Russia, and large investments of Japanese capital in the petroleum industry in one or all of those countries may be confidently expected in the near future.

More recent developments in the oil industry, since the above was written by Mr. Northrup, serve to emphasize the tendencies which he describes.

These quotations furnish the key for our future American

policy. Such mineral wealth as we possess in an exportable surplus must be managed for our best advantage. Such minerals as we do not possess in quantities sufficient for our own needs must be secured to us so far as possible by a definite and intelligent governmental policy.

I may digress somewhat to point out what appears our present best national policy as regards our own scanty supplies of this latter class of mineral commodities. There is at present an agitation among certain portions of our mining industry for the protection of some of these mineral industries which have developed through the stimulus of war shortage and high prices, and for rendering them permanent. From the national standpoint this would be shortsighted. We would be consuming our scanty reserves and would be impoverished in this respect more and more in the future. It is much better, for example, to trade our surplus of cotton and copper for the high grade chromite and manganese of other nations, being sure, however, to adopt such a moderate policy that our own reserves of such ores, in part at least, are readily available upon emergency.

Students of foreign trade in ores and of the mining industry of foreign countries, as well as our own, have noted that the competition of combined commercial interests other than the German, exists under official or semi-official guidance, and that, for example, the policy of the English in this regard is a very strong and deliberate one with which we have to count. This development is a natural one and we find the same impulse in American thought. Note, for example, our frankly expressed plans for capturing foreign trade and for having our merchant marine predominate on the seas. We can not, of course, do these things without taking wealth and power away from England and other maritime nations. Hence it is the right and intelligent policy for these nations to further their own interests just as we plan to do. However, if our policy is to be self-protective and nationalistic, as we state so openly, assertions are not enough: we must back these up by direct government encouragement and protection, such as is afforded the British and other nationalities by their governments. Americans, for example, or American companies (together with other foreigners) are debarred from owning or operating oil-producing properties in the British Isles, Colonies and Protectorates; but British-controlled companies have important holding in the oil fields of the United States, which they are extending.

In some of the mineral commodities, it seems very possible that there will soon develop, if there does not already exist in

some cases, a world shortage which may tend to grow more stringent, since the development of the arts requiring these materials will undoubtedly grow rapidly, while the natural supplies of these materials may not be increased in proportion. Therefore, there will be necessarily sharp competition between the United States and its best friends, such as England and Japan, as well as between us and our former enemies. This commercial struggle will have a certain tendency to terminate in the future precisely as it has in past history—in commercial and political intrigues, in bitterness of national feeling, and in wars. We may liken the commercial struggles of the respective nations to the cut-throat competition of rival commercial houses. The historic commercial-political struggle for the fur trade of North America between the British Hudson Bay Company, the French companies, and Astor's American Company in Oregon, is essentially what we may deduce in principle as the result of all great struggles for the enlarged trade and greater wealth of nations at the expense of each other. Speaking in the language of commerce, is this good business? Will it pay in the long run? Has it paid? Did it pay Germany, our best example? A continuation of this competition means for England an absolute necessity of keeping by means of her fleet the position of mistress of the seas. It means for America a program which has already been put forward, viz., the program for building a fleet as large or larger than England's. Competitive matching of navies to protect the commerce of their respective countries will end in the same way as competitive matching of armies—in war.

The only reasonable solution would seem to be for the rival houses to amalgamate. The plans for a league of nations are now under consideration, but there is grave doubt as to whether they will mature satisfactorily. If many nations, large and small, with different ideals shall seek to form a union, then it may be feared that no practical results will arise. It seems not only feasible, however, but imperative that the three nations which stand abreast in the forefront of civilization and are highest developed as regards fairness and good will toward the whole world, viz., the United States, Great Britain and France, should amalgamate for their own and the world's good, and agree upon a firm central policy with plans looking forward toward reciprocity or free trade, so far as it is fair, among themselves. Treaties will be no good; history has shown them to be what the Germans cynically termed them—"scraps of paper." The world has already tried a central judiciary and

has gained some fragments of international legislation but these have been of no avail to prevent war. Any league to be effective must be bound, not only by a central judiciary, but by a central legislative body, executive council, and a central military or police force by land and sea. But of even greater importance is the principle that for any league of two or more nations to be effective and permanent there must be commercial, as well as political alliance. The political league of the United States of America would not last long if there were interstate tariffs and discrimination in commerce by one state against the citizens of another.

Let this federation of the English- and French-speaking peoples be formed as a first step, and let it be tried out. By itself alone it would guarantee the world its peace. Other nations would be on probation and would be admitted one by one as they showed themselves desirous and competent, just as the territories of the United States have been admitted one by one to the brotherhood of states. This triple federation would safeguard the rights of peoples outside of the federation, to be well governed, to have their government administered for their own good, rather than for the advantage of exploiting powers or individuals. This does not mean that every state or tribe in the world should have the same voice in the world government as others. The Afghans can not have the same influence individually or collectively, as the Americans or British, except as they develop and show themselves more and more worthy, but it is the right and duty of the most advanced individuals and nations to see that nations like Afghanistan and India have the same fairness of government administered to them as the Americans or British.

FEUDAL TIMES IN VENEZUELA

By Professor A. S. PEARSE

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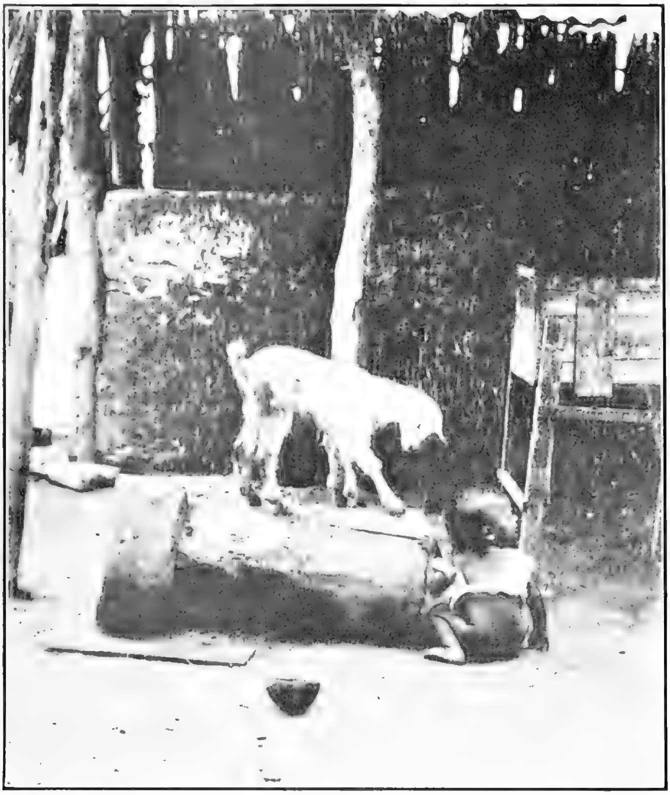
VENEZUELA has lately excited considerable newspaper interest and gained a rather unsavory reputation in the United States on account of its supposed pro-German sympathies. There have been rumors of submarine bases on the Venezuelan coast, of the proposed sale of an island to Germany, and other more or less wild tales. During the past summer the writer spent six weeks in Venezuela and was surprised to find that ninety-nine per cent. of the people were heartily in sympathy with the United States and the allies in their war against Germany. He became well acquainted with members of the president's family and heard President Gomez express his views on various matters of state, both foreign and domestic. This article attempts to give a true picture of conditions as they exist in Venezuela. If we are going to have business and political relations with South America, we must begin by understanding the conditions, customs and ideals in the countries with which we deal.

Venezuela is a beautiful mountainous country with great natural advantages. The mighty Orinoco drains the greater part of its area. There are fine grazing lands, fertile plantations and valuable mineral resources. Its three million people are intelligent, courteous, hospitable and good natured. Caracas, the capital, is a beautiful city nestling in a great natural bowl surrounded by mountains. This city is the most "stylish" the writer has ever visited. People are extremely well dressed. Every clerk carries a riding crop when he goes abroad in the evening.

All this fair country is owned by General Juan B. Gomez. To be sure, General Gomez does not have the actual title to all its estates, but his will is absolute and he may confiscate what he wishes at any time. He gained Venezuela, like the feudal barons of old, because he was and is the strongest man in it. When he retires the country will not be handed over to his son, nor to any one who may be elected president—*unless* this successor is a strong man. Castro was a strong man and a brave one. Gomez was the trusted commander of the army that made



"KIDS."

his government possible. When Castro's wild and erratic behavior compelled him to flee, Gomez took over the country by a "bloodless revolution."

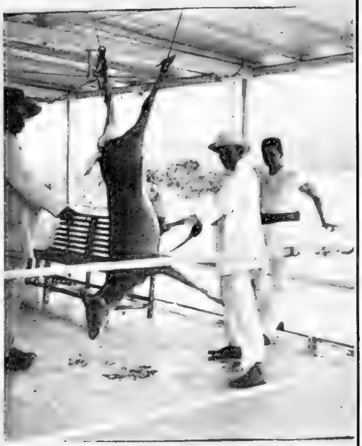
Gomez was elected president (every one of the little countries in Central America and the upper half of South America has a perfect form of government, on paper, and the laws are punctiliously observed, on paper). But having spent his days as a rancher and soldier, Gomez had no taste for an office-holder's life. He therefore appointed another man to wind the presidential red tape. Venezuela now has an "acting president," who does the administrative work, and a "president elect," who tells him what to do. This shows how much power Juan B. Gomez has. It also shows that Gomez is no weakling who received his inheritance from a proud but incompetent parent. Nor was he elected president because he could make a good stump speech; nor because he hired a big newspaper. His political machine was built of soldiers.

Under the present administration the people of Venezuela are better off than they have ever been before. On this account Gomez is generally respected and admired by his retainers. One of the general's hobbies, which he preaches constantly, is that every one must work—and in a real "mañana" country such an idea is revolutionary. Some of the old régime, who lay in soft berths as office-holders during Castro's time, are grumbling at home in amazed discontent, but people generally are rather pleased with the new order. One who works is now sure of some reward.

General Gomez is also liked because he has in general been just in regard to property and family rights. Though confiscation of land and other property by the government was an old, established, and of course always strictly "legal," means of income for office-holders in Venezuela, it has been administered with a considerable degree of justice since Castro's time. Of course, there are still abuses; politicians can not learn new methods in one generation. To-day it is much easier to get foreign capital into Venezuela than it was ten years ago, and

ON THE ISLA DEL BURO OUR PARTY SHOT THREE DEER IN AN HOUR. There are few game laws in Venezuela, but the slaughter of birds for plumes is prohibited.

TWO OF THE DECK HANDS ON A STEAMBOAT. There are no child labor laws in Venezuela.



A CABALLERO.

the "willingness" of capital is a good index of a country's stability.

Venezuela, though constitutionally and formally a republic, is actually as much an absolute monarchy as Russia ever was. The power of General Gomez is complete, and with this condition the virtues and evils inherent in absolutism obtain. The discipline throughout the country is like that of an army. One who commits a misdemeanor is speedily clothed in a fiery red convict suit and put to work twelve hours a day. Such quick justice is conducive to good behavior. The country is in general orderly, safe and quiet.

But "justice" is not always just. Unlimited power permits officials to vent private spleens. Sometimes men—often they are men of ability and prominence in the community—are thrown into prison overnight, and no one dares ask why. If the necessity arises, it is easy enough to find perfectly adequate legal reasons for such cases. On this account, foreigners who live in Venezuela do not often become citizens of the country. One specific instance will make conditions in this connection plain. A mechanic in a factory was told to come on Sunday to do some extra work. The man did not appear and

said on Monday that he had been sick. The owner of the factory, being a man of influence, sent the fellow on an errand; then called up the police station and gave orders to have him put in jail and kept there until orders were received to let him out. The workman stayed in jail two weeks.

Unlimited power is responsible for the detestable concessions, characteristic of most Latin American countries. In Venezuela it is customary to let the concession for selling stamps. One buys a stamp in one place and mails his letter elsewhere. There are government concessions for manufacturing, for selling, for transporting, for owning land. With power centralized as it is, these concessions are bound to be granted in many cases as rewards for political or military service or sold to those in favor with the government. Thus a few persons have most of the chances to make money. There is no general opportunity for everybody. A peon's son is expected to be a peon himself, and can rarely rise to a better position.

Culturally, Venezuela is of course rather backward when compared with more progressive nations. She has had and has some very good painters, as the admirable work in the National Art Gallery shows. There are excellent musicians and music is generally much appreciated by the better classes of people. There are a few good doctors, lawyers and teachers. The great mass of the people, however, are rather illiterate and the elementary schools are largely in the hands of the church. Domestic arrangements are usually rather primitive and often unsanitary, even in the cities. Cooking is done over charcoal

Bulls are the commonest draft animals in Venezuela.

VENEZUELAN GARDENER PLANTING YOUNG TREES. Seedlings are reared in joints of bamboo. When they are set out, one side of the "pot" is split off to allow the roots to spread, and the whole buried in the ground. In this way the roots are not disturbed and the bamboo as it decays furnishes nourishment for the young plant.

fires on the ground, or on an earth-covered table in the kitchen; the smoke being allowed to escape through holes in the wall. Most of the houses are made of clay with tile or thatched roofs. The natives are accustomed to close all the openings of bedrooms tightly at night, and, as would be expected, tuberculosis is prevalent.

But the next generation will see marked changes in Venezuela. There is a crying need for more and better opportunities for education. Caracas has already established two excellent trade schools, one for boys and one for girls. Even in the country districts one meets ambitious fellows studying at night to improve their position.

Under General Gomez the roads throughout Venezuela have been greatly improved. It is now possible to go comfortably from La Guaira to Porto Cabello by automobile. Concrete houses with yards about them are appearing here and there in the country districts. These are coming into favor and will undoubtedly in time replace the Spanish type of house (built of adobe clay around a central court)—which, though well suited for defense against attack, is neither pleasant nor sanitary.

In Venezuela the standards for chastity are somewhat dif-

ferent from those prevailing in the United States. The women in Venezuela are as careful in the observance of their moral code as those of any country, but their standards are not those commonly observed among English-speaking nations. One illustration will make conditions clear. President Gomez, though he has never married, is estimated to be the father of some hundred odd children. The laws of Venezuela permit a man to legalize the children any woman not his wife may bear, and the president has made such procedure for two families, which therefore constitute his legal heirs. Any man of wealth is likely to have a few odd children scattered about the country and no one thinks much about it.

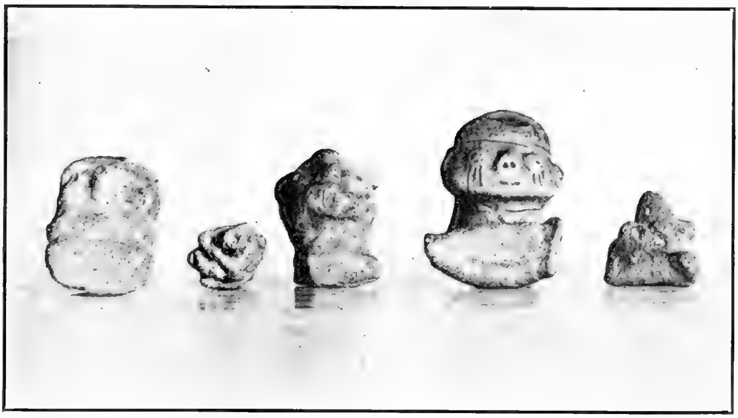
The most pathetic thing in Venezuela, as in all countries founded by the conquistadores, is the narrow life forced by custom upon the women. Any respectable woman sees most of the world through the iron bars of the windows of her "*sala,*" or living-room. A girl or woman who goes abroad without an escort is continually accosted by men. One American lady in Caracas said that the men frequently whispered things to her as she walked on the streets. One fellow who

TWO WOMEN POUNDING CORN FOR MEAL IN A MORTAR MADE BY HOLLOWING OUT THE END OF A LOG.

knew a little English hissed, "First prize!," in her ear as he passed.

Before the war Germany dominated Venezuela commercially. Numerous concessions were held by German firms and most of the capital which developed the country came from Germany. The well-known Germanic commercial methods were in vogue. Various schemes were practised in order to keep the prominent men of the country "in line." For example, General Gomez is said to have bought stock in a German company and to have received 1.5 per cent. on it each month for thirty years. There are many signs of German influence. The Venezuelan army wears typically Teutonic, spiked helmets, and "goose-steps." But as regards the recent war, the sentiment of the great mass of the people was with the allies.

Doubtless Venezuela will during the next generation or two lose much of the picturesqueness which makes it so attractive to-day. The free-handed hospitality of feudal times will have to give way to the suspicion and meanness attendant on commercial progress. A riper civilization will bring better sanitation, improved opportunities for every-day citizens, a broader outlook for women, better educational advantages, and other desirable changes. But the romance which always goes with grand estates dominated by great personalities must pass away. Feudalism will depart from Venezuela.



Ancient Indian idols, found on an island in Lake Valencia.

THE PROGRESS OF SCIENCE

THE ATLANTIC CITY MEETING OF THE AMERICAN MEDICAL ASSOCIATION

THE seventieth scientific assembly of the American Medical Association, held at Atlantic City during the second week of May, was notable as a celebration of the service of medicine to the nation in time of war. The attendance of members was about five thousand, nearly all of whom had taken an active part in national work, either as officers of the army and navy or in other directions. When the armistice was signed there were 35,000 medical officers in the army and 3,000 in the navy—more than one fourth of the entire profession of the country.

At the Atlantic City meeting there was a general opening session at which the president, Dr. Alexander Lambert, of New York City, gave the annual address and delegates from foreign nations were introduced. At a second general session national organizations, the activities of which have definite medical interest, were represented by speakers, each of whom gave a ten-minute address on the general subject of American medicine and surgery as it responded in service under war conditions. There were represented the Army, the Navy, the Public Health Service, the Red Cross, the Association of Military Surgeons, the American Health Association, the National Tuberculosis Association and the American College of Surgeons. The scientific papers and discussions of the meeting were presented before the fifteen sections into which the scientific assembly is divided.

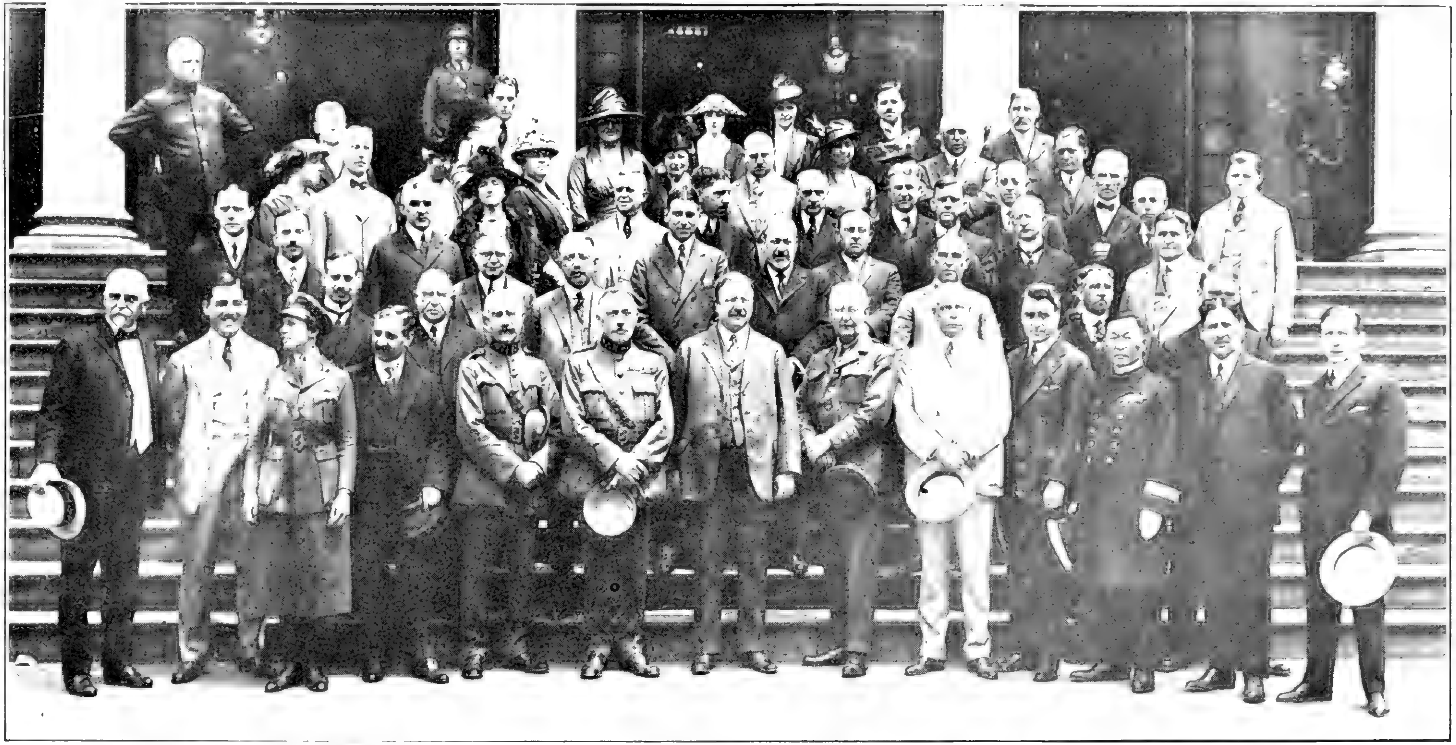
The American Medical Association is by far the strongest existing organization of scientific and professional men. It is based on component state and county societies whose total membership is over eighty-two thousand. Its excellent weekly journal has a circulation of nearly the same size. The total number of physicians in the United States is less than 150,000, so that more than half of them are members of their organization. The National Educational Association has a membership of only about 10,000 from among some 500,000 teachers. Teachers are now forming unions in many cities, but the American Medical Association and the state and county medical societies have long accomplished the same objects, attested by the high standards of the profession and its great service to the nation.

MEDICINE AS A DETERMINING FACTOR IN WAR

THE part played by medicine in modern warfare was reviewed by Dr. Lambert in his presidential address before the American Medical Association. The subject was in part treated historically to show the great change which has resulted from advances in medicine, surgery and public health.

In earlier wars the decision has often depended more on the wastage of the armies by disease than on their fighting. In the Thirty Year War, which began in 1618, the battle casualties were only a few thousand, but typhus, smallpox, bubonic plague, dysentery and scurvy, with famine added to pestilence, reduced the population of Germany from sixteen to four million.

The Crimean War, 1854–1856, is said to show the highest loss from battle casualties among the Russians, and from disease among the French, of all wars of which we possess accurate records. The battle death rate among the British was 69 per thousand per year, among the



FOREIGN DELEGATES TO THE MEETING OF THE AMERICAN MEDICAL ASSOCIATION

Among the delegates were: Sir St. Clair Thomson, Major General Sir Bertrand Dawson, Lt.-Col. Shirley Murphy, Sir William Arbuthnot Lane, Sir Arthur Newsholme, Dr. Ernest W. Hey Grove, Mrs. Eleanor Garton, and Col. W. T. Lister, England; General Melis, Col. A. Depage, Dr. P. Nolf, Prof. J. Duesberg, Capt. Van Der Velde, and Capt. René Sand, Belgium; Dr. Maurice Heitz-Boyer, and Dr. C. Mullon, France; Dr. Pedro Chutro, Buenos Aires; Dr. Juan Guiteras, Dr. Emilio Martinez, and Dr. Francisco M. Fernandez, Cuba; Dr. Israel Holmgren, and Dr. Sven Ingvar, Sweden; Dr. Peter F. Holst, Norway; Dr. John Constas, and Dr. Caroussos, Greece; Dr. Asajiro Kammimura, and Dr. Ryuzo Kodama, Japan.

French 70, and among the Russians 120. The disease death rate was 230 per thousand among the English, 341 among the French, and 263 among the Russians.

In the Franco-Prussian War of 1870, the Prussians reached the highest standard of protection against disease that any army had yet attained. The ratio of their battle casualties was 55 per thousand to a rate of death from disease of 25. The French, hampered by the quartermaster control of medical organization, in a demoralized, defeated army, suffered battle casualties of 68 per thousand and a rate of death from disease of 141. Among the French prisoners of war, smallpox broke out as a plague, about 14,000 cases occurring in Germany and about 25,000 in the interned army in Belgium. Smallpox followed as an epidemic in Germany, causing the death of 170,000 persons after the war.

Dr. Lambert reported that the death rate in our Civil War of killed and dying of wounds as 33 per thousand, the disease death rate as 65. In the Spanish War the death rate from battle was 5 and the death rate from disease 30.4 per thousand. The statistics of the American Expeditionary Forces, with an average strength of 975,716, reveal a rate of death from wounds in action of 31.2 per thousand and a death rate from disease of 11.2. Of those who died of disease, pneumonia claimed 9.1 per thousand.

In the Spanish-American War, 60.5 per cent. of all deaths were caused by typhoid, and in the present war 85 per cent. were caused by pneumonia. The pneumonia was mainly the result of the world-wide epidemic of influenza and the mortality of some American cities exceeded that of the camps. If the death-rate from pneumonia is subtracted the total death-rate from disease in the army at home and abroad is only 2.2 which is apparently less than the death rate of the men in civil life.

Dr. Lambert maintained that the importance of the Medical Department of the Army is such that it should be adequately represented on the General staff. In the concluding part of his address he drew the logical deduction from the medical lessons of the war, that this nation, through its present medical knowledge, has within its grasp the power to control communicable, and hence preventable, diseases, and that there must be established a nation-wide controlling organization for this purpose, a National Department of Health.

JOSEPH BARRELL

The science of geology has had great losses during the past year or so in the deaths of Grove Karl Gilbert, George F. Becker, William Bullock Clark, Henry Shaler Williams, Samuel Wendell Williston, and now a man of the greatest promise, Joseph Barrell. All of them have been leaders in geology or paleontology, and Barrell stood as high as the highest.

Joseph Barrell was born at New Providence, N. J., December 15, 1869, and died in New Haven, after one week of illness, on May 4, 1919. He leaves a wife and four sons. He was descended from George Barrell, a Puritan who migrated from Suffolk, England, and settled at Boston in 1637, and was named after his great-grandfather, a patriot and wealthy shipowner of Boston.

Barrell was thoroughly trained in engineering at Lehigh University, and later in geology and zoology at Yale. He took three degrees in course at Lehigh, B.S., E.M. and MS., and in 1916 that university gave him her doctorate of science. On this occasion President Drinker said: "Joseph Barrell—Distinguished scientist, a recognized

For Forty Years Professor of Cryptogamic Botany in Harvard University, by whose death the United States suffers the loss of one of its most distinguished men of science.

JOSEPH BARRELL

Late Professor of Structural Geology in Yale University.

leader in the study and teaching of geology, known and honored for his research and writings in the science of the earth in which the earth's history has been written by a mighty hand—Lehigh is proud of the record of this alumnus, whose life work has been so modestly yet so ably done, and through whose work his alma mater has been highly honored."

In 1893, Barrell began teaching geology at Lehigh, leaving to take his Ph.D. at Yale in 1900. Then he returned to Lehigh until he was called to Yale in 1903. In 1908 he was made professor of structural geology. Recognition of his work by his fellow workers in science came last April in the form of election to membership in the National Academy of Sciences, the highest honor that can come to any American man of science. He was also a member of the Sigma Xi and of Phi Beta Kappa, a fellow and councillor of the Geological Society of America, and a fellow of the Paleontological Society. He had traveled widely in North America and in southern Europe, studying in the field the interrelations and deformations of the geologic deposits and their wear and tear by the forces of nature.

Professor Barrell loved to work at the more difficult problems of theoretic geology, such as the genesis and age of the earth, isostasy, and the strength of the earth's crust. His studies on the principles of sedimentation and their climatic significance have received much attention. In paleontology, he presented evidence to show that the fishes arose in the waters of the lands, and that lungs were developed, under the most trying conditions of semiarid climates, out of air-bladders of fishes. Similarly, that man "is peculiarly a child of the earth and is born of her vicissitudes."

In childhood Barrell was thinking of things scientific, and was even then more fond of books of learning and travel than of fiction and poetry. He was preeminently an observer and a student, and his recreation was scientific reading. Due to his training as an engineer, he always retained a liking for mechanics and mathematics, and through their aid loved to delve deeply into the broader problems of geology and biology. It was, in fact, these wider interests and the ability to work along so many lines that made him the deep and original thinker that he was. His colleagues at Yale will miss his stimulating originality. To them he was a second James D. Dana, and curiously both had a strikingly similar likeness.

C. S.

SCIENTIFIC ITEMS

We record with regret the death of Walter Gould Davis, for many years director of the Meteorological Bureau of Argentina; of Lawrence M. Lambe, of the paleontological staff of the Canadian Geological Survey, and of Edmund Weiss, director of the Vienna Observatory for thirty-two years.

The John Fritz Medal of the four national societies of civil, mining, mechanical and electrical engineering has been awarded to Major General George W. Goethals, for his achievement in the building of the Panama Canal.

Dr. W. W. Campbell, director of Lick Observatory of the University of California, has been named head of an American delegation of astronomers that will attend the international meeting in Brussels in July.

Dr. Vito Volterra, professor of mathematical physics in the University of Rome, will deliver a series of six lectures on the Hitchcock Foundation at the University of California in August or September.

Sir Arthur Newsholme, K.C.B., who is now in the United States has accepted for the academic year 1919–1920, the chair of hygiene in the new school of public health of the Johns Hopkins Medical School.

THE SCIENTIFIC MONTHLY

AUGUST 1919

FORTUNES IN WASTES AND FORTUNES IN FISH[1]

By Dr. VICTOR E. SHELFORD

UNIVERSITY OF ILLINOIS

I. Introduction.

We have been at war with a well-organized nation which had planned and saved with war in view. In our belated endeavor to conserve existing resources and to develop new and latent ones, new problems arose and will continue to arise throughout the reconstruction period. Some of these concern fisheries and the pollution of waters. The United States Fish Commission has urged the public to eat fish, to make every day a fish day. This was no doubt done in the early days of our republic, for in a great strike of apprentices one of their chief demands was that they be not fed on salmon more than three times a week. Attention has accordingly been directed to the fact that where many fish ought to be there are few to be had. We find that fishes have greatly decreased. With only a brief survey of the situation one sees that the general problem of maintaining fishes against extensive catch and against pollution of waters with sewage and the waste products of manufactories is very complex. It is so complex indeed that in considering pollutions one may

[1] Contribution from the Illinois Natural History Survey and from the Zoological Laboratories of the University of Illinois, No. 124. For references to the literature of the subject and sources of information see, Bull. Ill. Nat. Hist. Surv., Vol. 13, Art. 12. The paper is the outgrowth of work done for the Nat. Hist. Surv.; The Dept. of Zoology, Univ. of Ill., supplied the illustrations. The writer is indebted to Professor S. W. Parr, Dr. Roger Adams and Mr. F. C. Baker for suggestions during the preparation of the manuscript.

write only from his experience and knowledge without assuming to have covered or exhausted the field.

The richness of the fish supply of our east coast in the early colonial days was beyond our wildest imagination. One early writer said of the shad of the Delaware and Susquehanna rivers, "They came in such vast multitudes that the still waters seemed filled with eddies, while the shallows were beaten into foam by them in their struggles to reach the spawning grounds." They swarmed every spring from mouth to headwaters of every river from Maine to Florida. Shad was undoubtedly the most important fish food in the early days of the nation. They were eaten fresh, and smoked and salted for winter use. During the spring runs people traveled long distances to shoal rivers to obtain their winter's supplies.

Along the Illinois River many years ago, buffalo-fish afforded the chief marketable species. These were caught by farmers, fishermen and others, and shipped by boat, principally to St. Louis. As no ice was used the fish frequently spoiled, or they were thrown away because the market was overloaded. Thus this great resource was depleted by careless and wasteful methods of catching and marketing.

The Atlantic salmon once entered all the rivers of New England; now it is the most expensive fish on the market. Our Great Lakes once yielded whitefish in abundance, but now the number is exceptionally small in comparison. Some of our Pacific-coast fisheries are likewise being depleted. Every stream formerly yielded fish to small boys and old men anglers. If any of these sources yielded half their original quantity it would now be counted a veritable fortune in fish.

Our fish resources have been depleted through neglect, carelessness and the pollution of waters. Such as are still left are endangered by new projects and new pollutions. There has been too much bald scientific and business sophistry in the matter. Ichthyologists, biologists, engineers, sanitarians, industrial chemists and business men, without consultation, cooperation or critical analysis, have proceeded on the basis of their imperfect and fragmentary knowledge to draw inferences as to the effect of this or that on fishes. The inferences of some scientists are not especially more in keeping with an equitable decision relative to a policy favorable to the public interest than was the exclamation of a manufacturer when confronted with a law intended to stop his factory from polluting streams: "What, stop a great industry because of a few fish!" The pollutions of manufacturing plants and city sewage have greatly

aggravated the depletion, or in some instances have completed the destruction previously started by heedless fishermen; but the pollutions are far more serious than the initial injury because they preclude the possibility of easy recovery. We have all sinned alike until it becomes imperative that we take stock of our knowledge, now that we are under the pressure of numerous problems demanding immediate solution because of the great war and necessary reconstruction.

The damage done in our fresh waters by pollution and obstruction of streams with dams with no adequate fish ways is almost incalculable. The great increase in manufacturing in the past fifty years has loaded our streams with poisons which have seriously furthered the destruction of fishes that were formerly available everywhere. To be sure the Mississippi and its larger tributaries supply fish, particularly carp, in quantity to the market and in the Illinois River, for example, the number of fishes at points about 200 miles or more from Chicago has been increased by increasing breeding grounds and the fertilizing of the waters by the Chicago sewage. When one considers that fishes have been wiped out for about 120 miles to bring an increase this far down the river, the gain proves after all to be a loss. The importance of pollution has been little realized in America, but progress along these lines has been very slow everywhere.

In Scotland about the year 1220 it was ordained that from Saturday night to Monday morning it should be obligatory to leave a free passage for salmon in all the various rivers. Almost seven hundred years later a very similar law was enacted in certain of our Pacific states, but the time is shorter, being from Saturday night to Sunday night. The absence of such laws in New England a century ago has caused infinite damage to salmon and shad resources.

In 1606 an act passed by James VI. of Scotland forbad the pollution of lochs and running streams because it was hurtful to all fishes bred therein. The punishment for violations were severe. Three hundred and twelve years later we are confronted with a problem of substituting fish for beef, pork and mutton and find our laws no better than the laws of three to seven hundred years ago and the native fish supply very much reduced through heedlessness and pollution with waste.

These wastes are numerous and have been less often preserved in America than elsewhere.[2] Tar is an important waste substance. At one time coal-tar was considered a nuisance in

[2] See "World Wide," Toronto, November, 1917.

gas-making, difficult to handle and difficult to dispose of. Tar is to be looked upon as the prize among waste products. It is unlikely that anything furnishing such an enormous number of useful substances will again be found nor can the enormous wastage of them in America be repeated again. The number of chemists who have investigated this substance is, of course,

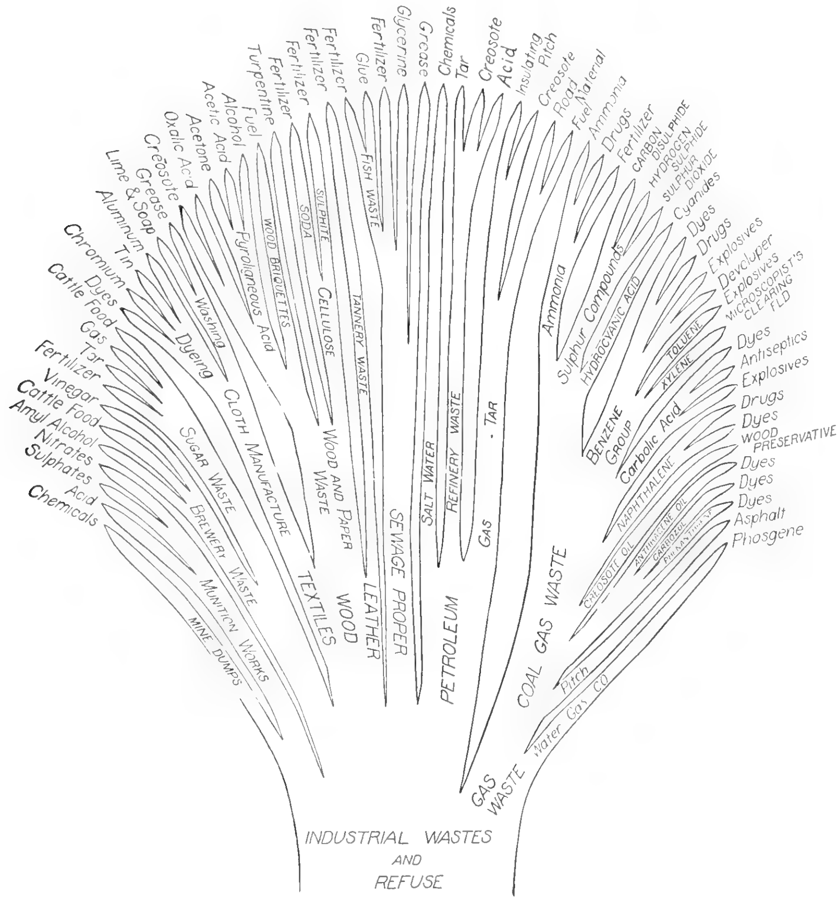


FIG. 1. Diagram showing, in the form of a tree, the various wastes and the useful substances into which they may be manufactured or which may be obtained from them.

enormous. It was in 1856 that Sir William Perkin produced the first dye to be made in large quantity. He was a successful business man as well as a chemist, and built and operated a dye factory in England.

There are numerous interesting cases of waste products that have proved gold mines to men who have found ways of

turning them into something useful. The volatile substances given off in the making of charcoal from wood, for example, have become very important. In the old way of making charcoal all these valuable products (wood alcohol, acetone, acetic acid, etc.) were entirely lost, but to-day they are the most im-

FIG. 2. Diagram showing the various wastes and the damage they do when not properly recovered.

portant of the substances obtained. The investigation of waste materials is often very fascinating, and sometimes leads to unexpected ends. This was the case with the waste earths from which materials used in the making of incandescent mantles had been removed. Small mountains of these wastes were

accumulating and Baron von Welsbach went to work to investigate them for oxides other than those used in the manufacture of mantles. By means of electricity he reduced some of these oxides, obtaining certain lumps of metal. In cutting a lump with his knife, he discovered a remarkable sparkling effect. He soon saw that this had commercial possibilities, and the outcome of it was the preparation of a form of gas lighter to replace matches. These metals have also played an important part in the great war as flares for lighting no-man's-land and in furnishing the various types of signals. This was a very important waste product.

As the years go on waste products are constantly disappearing from European industry and to a lesser extent from American. Great competition and the lowering of prices have made it essential for factories to utilize or dispose of all their waste material, and processes that leave large margins for waste have not much chance of success. Utilization of waste is necessary in America now that we have to make up for the enormous wastage of war.

Perhaps most of what one may call the sensational discoveries with regard to waste substances have already been made; but there is still a great field for research both in recovering useful substances and in rendering residues harmless to animals. There is the wood-pulp industry, for example. Over 145,000 cords of pulp-wood, valued at $800,000, were lost annually in Canada, and also large quantities of sulphur from the chemicals used. The waste liquors containing these substances have been discharged into rivers or the sea and are very poisonous to animals. There is a good opportunity to utilize sawdust, and to get more value out of it than in the past. It has been used for making artificial silk, and also for manufacturing alcohol. If alcohol should come to be used in place of gasoline for automobiles, this would, in all probability, prove a profitable means of obtaining it.

It would be a very great advantage to the tanning industry if really good use could be found for the spent tan and the various waste liquors. These are now used as fertilizer. It is agriculture that seems to get the benefit of a large number of the odds and ends of waste substances. If one can find no other use for a waste material, he can probably work it off either as a cattle food or as a fertilizer though at a very low price. But one must not pass blissfully over the damage the substances do when wasted as shown in Fig. 1 and Fig. 2. The fishes must be considered. Attention is accordingly turned to some of the specific needs of fishes and fisheries.

II. Fresh-water Fishes

1. *Their Needs.*—The presence or absence of fishes is controlled by (*a*) their ability to recognize the presence of strange or deleterious substances and to turn back when they are encountered, and (*b*) by their survival or death in situations where they can not escape the deleterious conditions. The sense organs with which they recognize strange or deleterious substances have been shown to be very elaborate and effective. Fishes recognize exceedingly minute quantities of numerous substances, for example, two parts per million of sulphur diox-

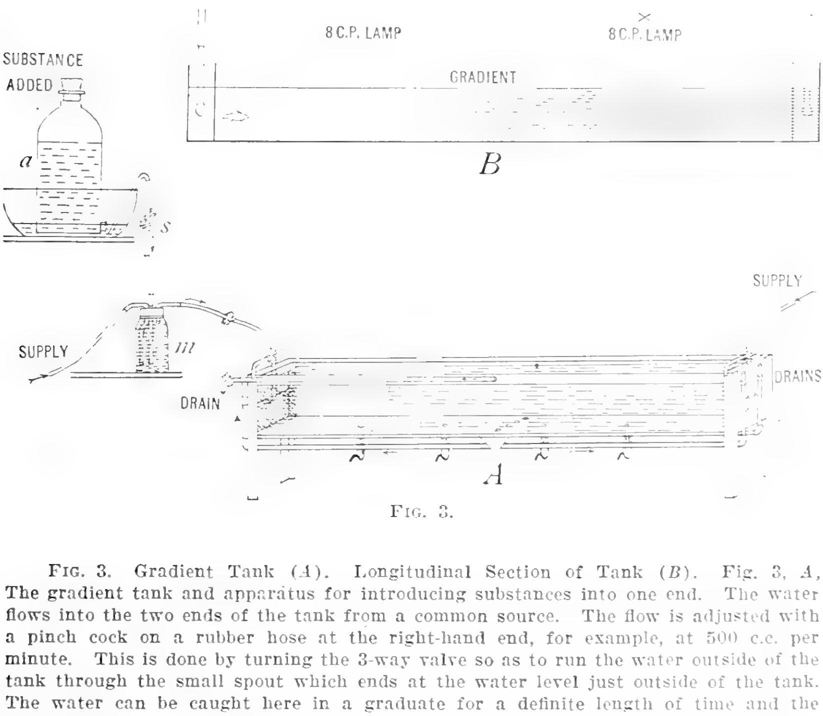


Fig. 3.

Fig. 3. Gradient Tank (*A*). Longitudinal Section of Tank (*B*). Fig. 3, *A*, The gradient tank and apparatus for introducing substances into one end. The water flows into the two ends of the tank from a common source. The flow is adjusted with a pinch cock on a rubber hose at the right-hand end, for example, at 500 c.c. per minute. This is done by turning the 3-way valve so as to run the water outside of the tank through the small spout which ends at the water level just outside of the tank. The water can be caught here in a graduate for a definite length of time and the flow per minute determined. The flow of water at the end into which the substance is added may be set at, say, 400 c.c. per minute and then sufficient of the solution added to the mixing bottle from the siphon above at the left (100 c.c.) to make this 500 c.c. also. The solution of a non-volatile substance is siphoned (see Fig. 1, *A*) from a dish in which is a 12-liter aspirator bottle (*a*) with the upper opening tightly corked and the lower one open. When the water in the dish falls below the level of the lower opening a few bubbles of air slip in and the same amount of fluid flows out, thus maintaining a constant level in the dish as long as the supply in the aspirator bottle holds out. Volatile substances have usually been added directly from the lower opening of the aspirator bottle. In this case it is necessary to correct the flows occasionally. The solution is run into a mixing bottle (*m*) which is connected in the flow of pure water. Fig. 3, *B*, shows a longitudinal section of the tank when a substance is introduced at the left-hand end. The substance is shown by black markings. The central portion shows a gradient between pure water (white) and the introduced substance (black lines). The graphs are drawn on the basis of the position of the fish in this longitudinal section.

ide, and not only turn back upon encountering them, but are able to recognize and orient their bodies with reference to increases and decreases of such substances often present in water.

The testing of these sensibilities of fishes has been carried on by means of experiments performed in a gradient tank, as shown in Fig. 3, *A*. Water of two kinds was used in the experiments. One kind was allowed to flow into one end at a definite rate and another kind into the other end at the same rate. The mixture flowed out at the middle, at the top and at the bottom so that the two kinds of water met at the center. The outflow at the center did not of course prevent the mixing of the two kinds of water in the tank and thus the middle section (broken line area in Fig. 3, *B*), equal to one half or one third of the tank, was a gradient between the two kinds of water. The tank used in these experiments was 122.3 cm. (49 in.) by 15 cm. (6 in.) by 13 cm. (5¼ in.) deep. The front wall was of plate glass and a plate glass top was used at times. Water was allowed to flow in at both ends at the same rate (usually 600 c.c. or about a pint per minute) through tee-shaped tubes, the cross bars of which contained a number of small holes. The cross bars of the tees were at the center of the ends of the tank behind screens. The drain openings were located at the center near the top and in the bottom. The outer openings of the drain tubes were at the level of the water in the tank. The water flowed in at the ends and drifted toward the center and flowed out through the drains. We found no evidence that fishes react to the slight current thus produced. Since each half of the tank held about nine liters (9½ quarts), it required 15 minutes to fill it or to replace all the water in one of the halves. The tank was enclosed under a black hood. Two electric lights were fixed above the center of the two halves, *i. e.*, above a point midway between the screen partition and the center drains. The light was 15–20 cm. (6–8 in.) above the surface of the water which was 13 cm. (5¼ in.) deep. The room was darkened during the experiments which were observed through openings in the hood above the lights or through the glass side late at night. Fishes do not usually note objects separated from them by a light.

Water differing as little as possible from that in which the fishes usually live was used for control readings. Controls were observed and the conditions in the two ends of these were the same either because the water introduced at the two ends was alike or because no water was run into either end (stand-

ing water). In the control experiments the two ends of the tank were alike and the fishes moved back and forth symmetrically (Chart I., Graphs 1 and 3; Chart II., Graph 5). When a gradient between two kinds of water was established, fishes put into the tank tend to go back and forth and thus encounter the experimental gradient. When the change of conditions thus encountered was such as to affect the fishes, they usually reacted either by turning back or by passing through the gradient into the treated water. But in the latter case they quickly returned to the untreated water, thus spending a shorter time

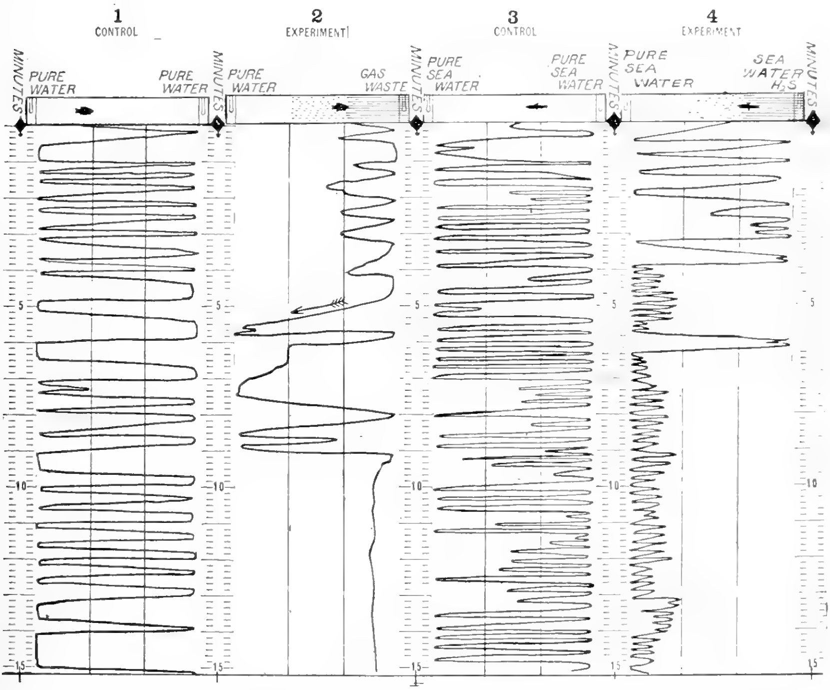


CHART I. Showing the movements of fishes in the gradient tank shown in Fig. 3 (*A* and *B*). Fig. 3, *B*, is repeated at the beginning of each graph; where the water was alike in the two ends it is shown clear. The kind of water is indicated above the figure. The scales at the sides are minutes divided into ten second periods. The fish is shown in black above the beginning of each graph and headed in the direction which the graph shows that it is moving. The back-and-forth movements of the fish are shown by the tracings from right to left in the graph. The length of time spent in moving, turning around standing still is indicated by the time scales.

GRAPH 1. Showing the nearly regular back and forth movement of a sunfish in pure water.

GRAPH 2. Showing the preference of the same sunfish for water containing gas waste and its turning back from purer water. The arrow indicates that it was driven into pure water.

GRAPH 3. Showing the nearly regular back-and-forth movement of herring in pure sea water.

GRAPH 4. Showing the sharp avoidance of sea water containing a little H_2S, after a few trials of the entire length of the tank.

in the treated water. In either case they are called *negative.*

Several species of fish,—large and small mouthed black bass, green sunfish, blue gill, crappie, golden shiner, sucker, and various minnows, were studied in detail. All these fishes were slightly negative or indefinite in their reaction to water containing little dissolved oxygen, *i. e.,* they turned back from or ignored water of low oxygen content. All the fishes were decidedly negative in their reaction to increased carbon dioxide. The differences tried varied from 5 c.c. (1/3 cu. in.) to 60 c.c. of dissolved gas per liter above that in which the fish had been kept. When increased carbon dioxide accompanied low oxygen the negative reaction was very marked; the fishes turned back when the gradient was encountered and only rarely entered the part containing the highest carbon dioxide and lowest oxygen.

Several workers have shown that carbon dioxide is very toxic to fish. It appears to be much more so than corresponding differences (24 c.c. per liter) in oxygen content. Fishes turn away when they encounter an increase of as little as 2 c.c. per liter. Since a large amount of dissolved carbon dioxide is commonly accompanied by a low oxygen content, and other important factors, the carbon dioxide content of water or more precisely the acidity or hydrogen ions (strongly alkaline waters excepted) is probably the best single index of the suitability of that water for fishes. Most species probably can not live where it exceeds 6 c.c. per liter during the breeding season.

2. *Breeding Requirements of Fresh-Water Fishes.*—Nearly all fresh-water fishes deposit eggs on the bottom. It is to the bottom that the dead bodies of organisms sink and decompose and, accordingly, at or near the bottom that poisonous products of decomposition occur in greatest quantity. Decomposition of the bodies of plants and animals results finally in gases such as ammonia, carbon dioxide, hydrogen sulfide, methane, etc., which diffuse rather slowly to the surface and into the atmosphere, and in blackened organic débris called humus. Thus the extent to which the gases occur is dependent upon the amount of decomposition and the circulation of the water. The same processes of decomposition which result in these gases consume oxygen and as a rule there is insufficient oxygen for eggs and young fishes. A small addition of organic matter may readily decrease the oxygen and raise the carbon dioxide to a point which weakens the eggs and favors fungus.

If a body of fresh water is to support the most desirable fishes it should have an area of clean sand, gravel or other ter-

rigenous bottom covered by from six inches to two feet of water and an area of emerging and submerged vegetation to supply food. It is probable that for the best results these three areas should be about equal. The terrigenous bottom should usually be free from blackened débris (humus), for this usually accompanies decomposition. There is nothing deleterious about humus provided the material in it has passed the early decomposition stages. Thus darkened bottom usually, though not always, indicates decomposition and bad conditions. Small quantities of débris may be eaten by débris-eating animals. The presence of gilled snails of the genera *Pleurocera* and *Goniobasis* in fresh water indicates clean bottoms. Various other organisms usually indicate pollution with sewage.

For many fishes an area of water more than four feet deep is relatively unimportant. The addition of sewage and other organic matter affects bottoms and therefore breeding conditions most. The young at the time of hatching are perhaps more sensitive than eggs, certainly more so than adults.

The destruction of breeding grounds in the Great Lakes is credited with the depletion of the whitefish supply. In 1871 Milner dredged eggs of the lake trout together with decaying sawdust. The eggs were attacked by fungus. In 1908 Clark expressed the opinion that through the accumulation of slow decaying woody material, water-logged lumber, and sewage, the chief breeding grounds of the Great Lakes had been destroyed and could not be recuperated. If the warning of Milner thirty-five years earlier had been heeded, they would have been much better than at present.

3. *Relation to Pollution.*—Sewage without the addition of industrial wastes merely consumes oxygen, and increased carbon dioxide and ammonia to a point where fishes can not live. It is particularly damaging to the young on account of its destruction of breeding grounds and production of conditions which can not be tolerated by newly hatched fishes. The introduction of sewage also favors the growth of fungi which destroy the eggs of fishes. Adult fishes usually avoid such contamination and hence, except where escape is not possible, adult fishes are not killed by it. Rivers receiving the sewage of large cities are rendered uninhabitable to fishes by the development of poisonous compounds just noted. The sewage of Chicago has rendered the Illinois River uninhabitable to fishes as regular residents for a distance of over 100 miles down stream. Some invertebrates are often able to live in rapids where sewage occurs because of the general aeration of the water.

The resistance of different useful aquatic animals to polluting substances varies greatly, as does also that of their living food. In the case of fish, for example, it is not sufficient to secure for making tests any fish that may be convenient. The tests of toxicity must of course be of a character to determine means of affording protection to fish, but not to fish alone; the organisms on which they feed are perhaps commonly more sensitive than the fishes themselves.

The following table, based largely on the work of Dr. M. M. Wells, gives an estimate of the relative resistance of several widely distributed species of North American fishes. While it needs careful verification by new methods, it will serve as a rough provisional guide. It is based largely on death in waters containing little oxygen and much carbon dioxide. Since fishes rank differently in resistance according to the poison in which they are killed, the immediate need for further investigation is obvious.

TABLE I

Indicating the relative resistance of a very sensitive minnow and of some common game-fishes of the eastern and central United States and of the goldfish. The resistance of the least resistant species is arbitrarily taken to be unity

Species of Fish	Relative Resistance	Species of Fish	Relative Resistance
Labidesthes sicculus (Brook silverside)	1	*Ambloplites rupestris* (Rock bass)	10
Moxostoma aureolum (Red-horse)	2.3	*Perca flavescens* (Yellow or American perch)	10
Catostomus commersonii (Common sucker)	2.4	*Lepomis humilis* (Orange-spotted sunfish)	12
Micropterus dolomieu (Small-mouthed black bass)	5	*Carassius carassius* (Goldfish or Crucian carp)	12
Micropterus salmoides (Large-mouthed black bass)	6	*Lepomis cyanellus* (Blue-spotted sunfish)	15
Pomoxis annularis (White crappie)	8	*Ameiurus melas* (Black bullhead)	45
Pomoxis sparoides (Black crappie, Calico bass)	8		

Tests of the minimum quantity of poison which will prove fatal must be made on the most sensitive stage. The strength of a chain is the strength of its weakest link. A little has been accomplished in the study of poisons; the most sensitive period is not known for a single fresh water species of which the entire life cycle has been definitely studied. There is only a little information relative to fishes of different ages.

TABLE II

Showing the relative resistance of different sizes of two species of fresh water fishes. Based on work by Dr. M. M. Wells

Species	Condition	Weight	Relative Resistance
Rock bass	CO_2 and low O_2	1.9 gram 20–40 grams	1.00 5.00
Common shiner	CO_2 and low O_2	0.6 gram 21.0 grams	1.00 3.00

The matter does not end with these biological differences but the toxicity of different substances differs greatly.

TABLE III

Showing the relative toxicity, on a basis of weight, of different substances when added to distilled water. The figures are only approximate, but the great toxicity of acids and alkalies is evident. The higher the figure the greater the toxicity of the substance. All are compared with common salt, which is taken as 100 based on gold fish work by Dr. Powers

Animals Tested	Poison	Relative Effect	Poison	Relative Effort	Poison	Relative Effect
Fresh-water fishes (based on amount required to kill in 45 min. to 3 hrs.)	Common salt	100	Calcium acid sulfite	10,000	Magnesium sulfate	15
	Hydrochloric acid	40,400	Potassium chloride	50	Ammonium sulfate	400
	Sulfuric acid	15,000	Calcium chloride	59	Sodium nitrate	54
	Nitric acid	23,000	Barium chloride	60	Calcium nitrate	118
	Carbonic acid	3,700	Magnesium chloride	77	Magnesium nitrate	105
	Slaked lime	15,000	Ammonium chloride	300	Ammonium nitrate	232
	Ammonia	30,000				
	Calcium sulfite	22,000				

The great toxicity of acids is evident. The addition of acid to water containing carbonate is accompanied by the liberation of CO_2 and though its toxicity is only about one tenth that of mineral acids, it may be released in quantities very harmful to fishes. In all such cases the precise hydrogen ion concentration should be determined. Limestone is often used to neutralize acid, sometimes to doubtful advantage.

Just after the beginning of the European war the writer undertook the investigation of the effects of wastes from the manufacture of illuminating gas upon fishes. This form of pollution is common in the streams and is probably one of the most important on account of the extremely poisonous character of the coal tar compounds. The most valuable compounds are most poisonous. Benzene, xylene, toluene are used in mak-

ing explosives and hence of much value, and at the same time they are the most poisonous compounds occurring in the wasted gas liquor in the gas plants. These substances are usually referred to as insoluble and hence likely to be regarded as not of importance in causing the death of fishes. All, however, are slightly soluble in distilled or ordinary stream water. The amount going into solution readily kills the best food fishes in a few minutes. Tarry material holds much of these substances in solution and continually gives it off. Carbon monoxide is one of the most poisonous substances in gas and remains in standing water exposed to the air and continues to kill fishes for weeks. Naphthalene (moth balls) is extremely poisonous, commonly called insoluble, but is soluble enough to kill fishes very quickly. Representatives of nearly all the groups of compounds found in coal tar and gas liquor are deadly to fishes and 90 per cent. of the deadly compounds do not repel fishes (Chart I., Graph 2). When they encounter these compounds, they do not turn back but swim into them. Afterward on encountering pure water they turn back into the poison though it causes death within a few minutes. Mixtures of the compounds are equally or more deadly. Gas liquors, tar "drip" from the pipes are very toxic, 2–40 parts per million kill the more hardy species of fish in an hour. The wholesale destruction of fishes by these wastes occurs at times especially during cold winters. The remedy for this is the complete recovery of all coal products.

4. *Examples of Destruction of Fresh-Water Fishes.*—In January, 1916, in a small river below a town of 50,000 inhabitants large numbers of dead fishes appeared at breaks in the ice. Others in a half intoxicated state were caught through holes in the ice. Three thousand pounds of fish were caught in three days but could not be eaten because of a bad taste said to resemble gas waste. The case was investigated by the Illinois Water Survey. The death of the fish according to their report was due to lack of oxygen and poisoning due to stream pollutions, brought about by sluggish flow and heavy ice cover which prevented aeration. A similar occurrence with less destruction of fish was investigated by the same bureau but the destruction was less, probably due to gas waste not being present as in the first case.

Another case investigated by the writer occurred in a large creek when covered with ice. Fishes in a half intoxicated condition came to holes cut in the ice. Many fishes were taken but proved inedible because of a bad taste. When the ice went out

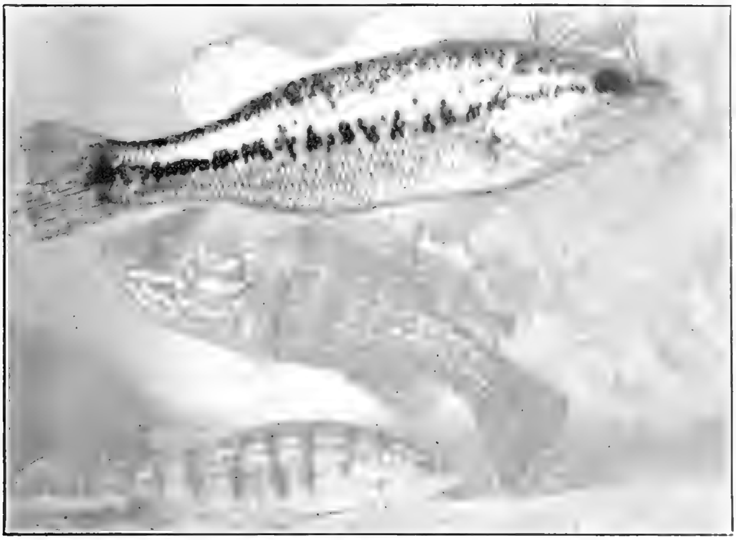


FIG. 4. Fishes common in the Calumet River before sewage was introduced. The upper fish in the foreground is a young large mouthed black bass. The central fish is a half-grown blue-spotted sunfish and the bottom fish is a small perch.

dead fishes were numerous, including carp, large and small mouthed black-bass, crappies, and sunfishes. The bullheads were the only ones which were not killed. There was a bright iridescent film under the ice and an odor of coal gas. This point is 25 miles below a community of 25,000 with a gas plant that pumps gas liquor on to the ground where it gets into the drainage sewers and into the stream. The point where the fishes were killed is a state fish preserve with special penalties for anything but very restricted fishing! The gas plant which is probably to be credited with destroying the fish did not recover anything but the heavy tar. The valuable hydrocarbons, ammonia, etc., are wasted. The destruction of fishes by industrial waste has been common throughout the country, especially within the past thirty or forty years. The fishes destroyed include those which occurred in commercial numbers, such as shad, salmon and whitefish and numerous game fishes such as perch, black-bass and sunfishes shown in Fig. 4. These disappeared in the Calumet River for a long distance below the point of introduction of sewage. Mussels (Fig. 5) survived in the rapids (Fig. 6) only a mile below the entrance of a large sewer. This is possible probably on account of the aeration of the water. The treatment of sewage with compressed air in the presence of activated sludge is effective in reducing its toxicity to fishes.

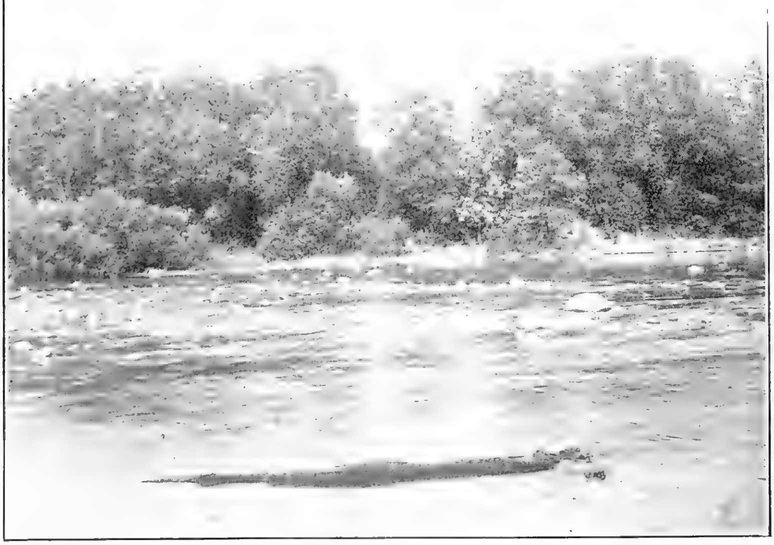


FIG. 5. Mussel shells on the bank of the Calumet showing the work of the pearl hunters. They were taken from the rapids shown below in Fig. 6. The mussels have survived the sewage which enters a mile above, probably because of the aeration at this point.

FIG. 6. Showing the Calumet River at the point mentioned above. The log in the foreground is blackened with sewage.

III. MARINE FISHES

1. *Their Needs*

Marine fishes are comparatively less resistant than fresh-water fishes to the products of decomposition in salt water

which results in carbon dioxide and hydrogen sulfide. On the whole the presence of a small quantity of carbon dioxide (lowered alkalinity) in the water affects the fishes less than a smaller amount of hydrogen sulfide. The combination of hydrogen sulfide and carbon dioxide was most rapidly fatal. Since decomposition yields carbon dioxide, consumes oxygen, and is accompanied by the production of hydrogen sulfide which also consumes oxygen, it is reasonable to suppose that on a bottom from which vegetation is absent and decomposition actively takes place, a fatal combination of lack of oxygen, and presence of hydrogen sulfide and probably carbon dioxide can develop quickly. In enclosed arms of the sea when circulation is cut off in the summer, oyster beds are sometimes killed by the presence of quantities of hydrogen sulfide. The destruction of fishes is probably not common, however, because of their negative reaction to it.

2. *Reactions of Marine Fishes*

A. *Hydrogen Sulphide.*—Herring turn back sharply from all concentrations of hydrogen sulphide not great enough to cause intoxication (Chart I., Graph 4). They avoid it sharply and turned about at a point where the concentration was equal to that under the *Ulva* on the sandy bottoms of a bay. The controls (Chart I., Graph 3, and Chart II., Graph 5) of these experiments are symmetrical, there being turnings from each end in about equal numbers. It shows the reaction of the fishes when no stimuli are encountered in the tank.

B. *Salinity and Hydrogen Ion Concentration.*—The fresh water supply of the Puget Sound Biological Station, when the experiments were performed, was from deep wells. It was very alkaline, containing no free carbon dioxide and only 0.5 c.c. per liter of oxygen. This water was aerated, which raised the oxygen to 4.8 c.c. per liter. This water was run into one end of the gradient tank and sea water into the other. In the experimental tank the difference between the density of the fresh and salt water was so great that the fresh water extended nearly to the opposite end at the top with very little mixing and the salt water occupied a corresponding place on the bottom. Thus there was a sharp gradient from top to bottom, but a very imperfect one from end to end. To avoid this difficulty a screen inclined cage was used (see headings of Graphs 6 and 7, Chart II.). The fish moved back and forth in this at a distance of about 4 cm. from the lower screen. The gradient of salinity between the acid sea water and the alkaline fresh water was

essentially perfect as shown in Chart II., Graphs 6 and 7; the oxygen content was essentially the same throughout. The salinity in the salt water end was two thirds that of normal salt water and one third in the fresh water end. Phenolphthalein indicator showed that the central region had about the hydrogen ion concentration of sea water (pH 8.0). It appears from

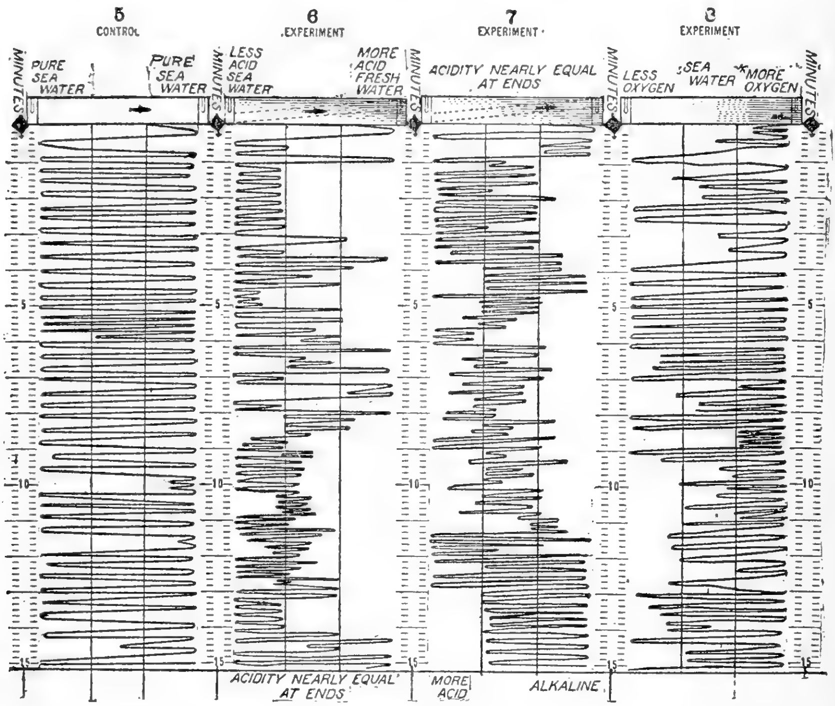


CHART II. For general remarks see Chart I.

GRAPH 5. Showing the regular back-and-forth movement of a herring in pure water.

GRAPHS 6 AND 7. Showing the selection of a less acid water and the shifting of the position of the fish from the left to the right hand end as the acidity slowly changed. In this case the herring selected the alkaline fresh water, ignoring the salt which is important to marine animals. The fish was confined between inclined screens because of the difference in density of fresh and salt water.

GRAPH 8. Showing the selection of water with most oxygen by a herring.

a number of experiments that the herring selected either brackish or quite alkaline water (pH above 8.0).

To determine whether or not this peculiarity is a reaction to salinity or alkalinity, the experiment with herring was repeated and carbon dioxide to which the fish are negative run in the fresh water, to neutralize the alkalinity. At the beginning of the experiment shown in Chart II., Graph 6, the carbon dioxide content of the fresh water was 26.5 c.c. per liter (prob-

ably about neutral pH 7.0) and the reaction was very sharply negative to fresh water. The concentration of the carbon dioxide in the fresh water was gradually lowered and the avoidance fell off, as is shown in Graph 7, which was really only a continuation of Graph 6 interrupted to take a sample which showed the carbon dioxide content to be 8.1 c.c. per liter. During the period represented by Graph 6 the negative reaction decreased gradually until a point was reached when the tank was probably about the same throughout, after which the fish became negative to the sea water at the end of 13 minutes, when on the basis of a uniform decrease, the sea water, which often has an hydrogen ion concentration somewhat greater than "normal" sea water which the herring usually prefers, became more acid than the fresh. Thus it appears that these fish are as sensitive to acidity as litmus paper. The young hump-backed salmon reacted similarly. They had just left fresh water and were caught at sea.

The relation of the two species of fishes to salinity is interesting in this connection as they ignored enormous differences entirely and reacted only to acidity and alkalinity (the herring being able to recognize the difference between pH 8.0 and 8.1). The salmon goes into fresh water to breed and some may reach maturity there or they may return to salt water at varying ages. The orientation of these specimens with head in the fresh water is of interest but it was evident that it was with reference to acidity and alkalinity (hydrogen ion concentration) rather than salinity. Sea water is less acid than the fresh water of salmon streams and the reactions of the salmon accord with their recent entrance into salt water.

The oxygen in the sea water in use at the station never reached saturation. One experiment was tried with water drawn directly from the tap, against water aerated by running over a board. The fishes selected the aerated water; the preference (Chart II., Graph 8) for the higher oxygen content was decided.

The resistance of different species of marine fishes differs as it does in the case of fresh-water fishes. Table IV. shows the relative resistance of several Pacific coast species.

TABLE IV

Showing the relative resistance of several species of Pacific Coast fishes

Hypomesus pretiosus (Surf smelt)	1
Clupea pallasii (Herring)	1.2
Cymatogaster aggregatus (Viviparous perch)	6
Psettichthys melanostictus (Flat fish)	18

3. *The Breeding Requirements of Marine Fishes*

The importance of factors which kill fishes is greatest in the early stages for three reasons. First, the small size of the eggs and embryos makes the ratio between volume and surface smallest and thus any substance in solution will reach all parts of the organism at a most rapid rate. Secondly, the inability of the eggs and embryos to move about makes them the easy victims of any adverse conditions that may occur. Thirdly, the resistance of the eggs to fatal concentrations of poison decreases to the time of hatching, being least then and rising as the fish grows larger. The eggs of the herring are deposited on the bottom. Nelson mentions rocks only and rocks are usually swept fairly clear of organic matter and the water well aerated down to the depth of one fathom where the fishes breed. If this means that sandy bottoms of bays are avoided, it prob-

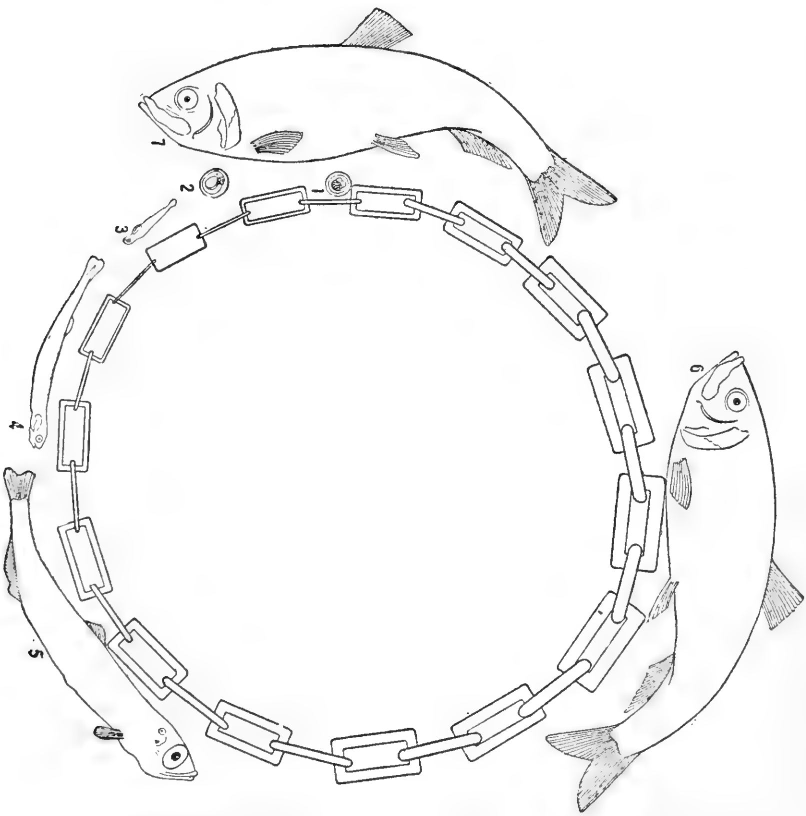


FIG. 7. Showing the life history of the European herring in the form of a circle, about a chain of links of differing strength. The weakest link is shown opposite the young at hatching but it is not known whether it should be here or at some near by point. The adults are weaker during the breeding season.

ably includes the avoidance, during breeding, of water containing much hydrogen sulfide which would be fatal to small herring fry to a greater degree than to those studied, which were 6 cm. long. Sensitiveness to hydrogen sulfide is a matter of much importance from the standpoint of the suitability of a given arm of the sea for herring and the influence upon fishes of contamination of the shores with refuse from the land. Acidity is not great in such shallow water on account of the absorption of CO_2 by the numerous plants for photosynthesis. However this does not prevent the development of much acidity at night. The eggs of nearly all marine organisms that have been studied require alkaline medium (pH above 7.0) for development. This has been demonstrated, for sea urchins, starfishes and plaice.

In the case of marine animals as in the case of fresh water ones there is a most sensitive stage. For fatal doses this falls at some time in the early free swimming stages or about the time of hatching. In the case of weaker concentration the youngest developmental stages of the egg appear to be most easily injured and rendered abnormal, which is often quite as detrimental to the species as fatal doses. Both types of effect are shown below in Table V. The life history of any animal may be represented as an endless chain (Fig. 7).

TABLE V

Showing differences in sensitivity of various stages of several marine animals. Most sensitive stage rated as 1. No basis for a comparison of the species. Based chiefly on the work of Prof. Child and of Whitley on plaice eggs

Species	Poison	Relative Resistance of Different Stages		Criterion
Starfish	KCN	Unfertilized egg	9.00	
		Blastula to gastrula	1.00	Fatal dose
		Young bipinnaria	2.00	
Sea-urchin	KCN	Unfertilized egg	3.88	
		Early gastrula	1.00	" "
		Prepluteus	1.50	
Clam-worm	KCN	2–4 cell stage	18.00	
		Larva with 2 pairs of setæ	1.00	" "
		Advanced larva	3.30	
Killifish	Phenyl urethane	2-cell stage	6.00	" "
		Hatching	1.00	
Tautogolabrus	Phenyl urethane	15 min. after fertilization	43.00	
		Heart beating	1.00	" "
		Newly hatched	1.25	
Plaice eggs	Acid	Fresh-laid	1.00	Unsuccessful development
	Acid	10 days old	10.00	
Plaice eggs	Alkali	Fresh-laid	1.00	Unsuccessful development
	Alkali	10 days old	2.00	

Different inorganic substances differ greatly in their toxicity to marine animals; acids are much more toxic to marine than to fresh water animals.

TABLE VI

Showing the relative toxicity—on a basis of weight—of different substances in distilled water. The great toxicity of acids and alkalies is evident. The higher the figure the greater the toxicity of the substance. All are compared with common salt, which is taken as 100. Based on the work of Prof. A. P. Mathews

Animals Tested	Poison	Relative Effect	Poison	Relative Effect
Marine *Fundulus* eggs (based on least fatal dose)	Common salt..........	100	Strontium chloride....	53
	Hydrochloric acid......	249,500	Sodium sulfate........	97
	Potassium chloride.....	70	Sodium nitrate.......	69
	Calcium chloride.......	185	Potassium nitrate	38
	Barium chloride	56	Sodium hydroxide....	14,610
	Magnesium chloride....	113	Potassium hydroxide..	6,200
	Ammonium chloride....	88	Barium hydroxide....	8,100

The sea water has an extraordinary capacity to neutralize acid. A liter of sea water will almost neutralize a liter of one five-hundredth normal acid and thus the toxicity of acid as shown in the table for pure water is greatly exaggerated as compared with additions to the sea.

4. *Examples of the Effect of Pollution, etc.*

(*a*) *Herring.*—By the method just described it is possible to obtain unusually accurate data on the factors influencing the movements of fishes. According to Marsh and Cobb a great difficulty in the herring fishery of the north Pacific coast is the erratic movements of the fish. Schools may visit a bay for three or four years, in succession, and then, without any apparent reason, avoid it for a season or two altogether. Bertham noted a possible relation between the abundance of these fishes and weather and suggests that climatic causes may have more to do with the failure of some branches of the fisheries than is generally believed. He attributed the failure of the fisheries of Cape Benton to the occurrence of severe east and northeast storms during the running season. It is clear that such storms may affect the dissolved content of the water by raising decomposing matter from the bottom. The English investigator Johnstone has said that it is now nearly certain that the shoaling migrations of the herring of Europe are to be associated with the salinity and temperature of the sea, but it is evident from the experiments described above that acidity and alka-

linity are more important than salinity and the solution of the problem will come from a careful study of the reactions of fishes along with a similar study of conditions in the sea.

The extreme sensitiveness of the fishes studied, as shown by their detection of slight deviations from neutrality, of small fractions of a cubic centimeter per liter of hydrogen sulfide, etc., makes it very clear that there is no difficulty in fishes determining the direction to large rivers from hundreds of miles out at sea or of finding their way into any bay or harbor or river or other arm of the sea which their particular physiological condition at a given time demands. It is not necessary to appeal to "instinct" to explain the return of certain salmon to certain rivers, or the running of herring in certain localities. The mere fact of their origin in the region, the probably limited tendency to leave it coupled with their ability to detect and follow slight difference in water is a sufficient explanation of all their peculiar migrations. The close way in which animals stay about certain localities from generation to generation is hardly appreciated. Thus, as Johnstone points out, the herring of the east coast of Britain are largely local, having formerly been assumed to belong to shoals that came from distant points.

The experimental method can not of course determine the cause for the absence of fishes from any given point but must be accompanied by hydrographic studies. Such combined efforts give trustworthy results. Hydrographic studies alone may lead to entirely erroneous assumptions because of the lack of knowledge of the sensibilities of the fishes concerned and the selection of some insignificant factor correlated with their absence or presence, as an explanation. Such correlates, offered as explanations, become the basis of erroneous remedial measures.

Noting the remarkable discriminations of fishes for differences in alkalinity, acidity and neutrality, a note of warning may be sounded in regard to the relation of pollution to runs of herring. The avoidance of the decomposition products is a sufficient explanation of the absence in valuable numbers of many other fishes. Their tendency to avoid acid waters, hydrogen sulfide, etc., which result from decomposition and are increased by the presence of refuse of fish canneries, sewage, etc., makes diversion of such refuse from the sea an important consideration. The Baltic towns of the Hanseatic League were dependent in part upon the herring industry and after a century of great growth and prosperity fell into decline at the middle of the fourteenth century. Their prosperity was the

accompaniment of the presence of great shoals of herring off the Island of Rügen in the Baltic. Their decline was caused in part by the failure of the herring industry and the supposed migration of the herring to the North Sea which has since been the center of the industry. Schouwen (on the Netherland coast of the North Sea) appears in the fourteenth century to have been frequented by the herring shoals in preference to Rügen. The rapid growth of the Netherland cities, their supremacy and final separation from the Hanseatic league followed. A little later the herring again changed their haunts, choosing the coast of Norway, where both Norsemen and Netherlanders caught them. The Beukelszoon method of curing herring having come into use, nearness to home was no longer a necessity. The Norse fisheries flourished until 1587, when an "apparition of a gigantic herring frightened the shoals away." Thus it appears that the development of the herring industry in each locality led to desertion of the locality by the fish, though the migrations assumed by historians are doubtful. Was this due to the contamination of the sea by the cities, or merely to over catch? Whichever may have been the case it is certain that contamination will not invite runs of the herring.

(*b*) *Cod.*—The cod eggs are pelagic and usually deposited in December or during the winter. The development takes place in the shore waters. The reduction of the cod supply of New England was associated with the building of dams across all the principal rivers and was attributed to the shutting out of the alewives, salmon and shad which were important articles of diet of the cod. It is far more likely that the construction of large factories which poured refuse into the sea destroyed the eggs through the lowering of alkalinity which prevents development.

IV. Present Day Problems and the War

The present great increase in manufactures and the excessively cold winter of 1917–18 with sluggish flow of streams may be expected to decrease available food fishes in inland waters. Industries using coal, gas plants, etc., are throwing much waste into streams which will destroy fish, not because they do not appreciate its value, but because being unprepared for peace they are unprepared for war.

Recently the gas company in the city of X with 25,000 inhabitants could not work up certain of its gas by-products and was storing them in reservoirs. If a market has not opened, this will find its way into the nearby stream. There was at the out-

break of the war no adequate market for coal, oil or water gas by-products. We have been and are still destroying or throwing away our most valuable coal-gas by-products. Material for munitions in enormous quantities were cast into our streams to bring untold destruction to fresh-water fishes before the war began. Until very recently under the pressure of the war there was no attempt to save these gas by-products from the smaller plants. Since interest in the by-products is increasing, many plants have attempted to save more than tar. Most of the small plants are entirely unadapted to save anything but heaviest tar and gas. The rest, with its innumerable valuable dyes, drugs, flavoring substances and explosives, is still cast into streams to kill fishes! Shortly before the war less than 25 per cent. of the coal coked in the United States was coked under conditions of complete recovery of all products. Now the percentage has increased to about fifty.

In the study of effects of pollutions on useful aquatic animals there has been too little in the way of clear statements of the problems involved. Under the pressure of the questions brought forward by the war, the writer has formulated the following nine questions involved in the solution of pollution problems.

1. In the study of the effects of pollutions test animals must be used. Is the animal selected one of representative sensitiveness? The tables on fishes (pp. 108 and 115) show the need of care in selecting test animals. The common suckers are recommended as suitable fresh-water animals for tests. They are widely distributed, easy to obtain, easy to recognize, and are representatively sensitive. It is also comparatively easy to determine accurately when an individual is dead. Dr. Powers found that to touch the tip of the tail of a fish to acid would determine whether or not it was dead. Herring are representatively sensitive marine fishes.

2. What is the most sensitive stage in the life history? (See pp. 109 and 117.)

3. When is the pollution most concentrated?

In fresh water, pollution will, as a rule, be most concentrated during seasons of drought or in extreme low water in winter; but to this rule there are many exceptions. Pollutions which float will do most damage during storms or high winds. This source of danger is greatest in the sea. Ice in winter prevents aeration and hinders circulation, and seems to have been responsible in Illinois for important losses of fish due to pollution. Many poisons are more toxic at high temperature than at low.

4. What is the toxicity of untreated polluting effluents; of each residual of processes of partial recovery; or of treatment by additions to the effluent? This can be determined by extensive experimentation only.

5. Do animals turn back from the polluting substance and thus escape destruction, or do they swim into it and die? (See p. 105.)

The acids from munition works have attracted attention of late. An effluent composed of 0.13 to 0.4 per cent. of acid—a mixture of 2 parts of sulfuric acid and 1 part of nitric acid—is discharged by guncotton works. This acid effluent flowing into the brackish waters of the coast of New Jersey repelled the killifishes, on which the keeping down of mosquitoes depends. It was proposed to treat the acid effluent with lime, and the question of the effect of the calcium nitrate on marine fishes became a problem for immediate solution. A number of tests of herring and viviparous perch in the summer of 1918 showed that they are attracted by the calcium nitrate. Similar problems are arising in connection with inland rivers. Large quantities of such acid is now being run into the Sangamon River by munition works at Springfield, Ill., and into various other waters of that State.

6. Do polluting substances cover the bottom and make conditions unfavorable for eggs?

The majority of important fresh-water animals—mussels, which furnish pearl for buttons, whitefish, bass, sunfish, etc.—are dependent on the bottom for breeding, living conditions or food. If the contaminating substances are covering breeding bottoms of bare sand and gravel they are dangerous to fishes.

7. If the supply of useful animals is depleted will recovery be rapid or slow?

Petersen and Jensen found that if the flora and fauna were removed from marine bottoms useful animals such as oysters can not again live on them until a series or succession of plants and animals has prepared the way. The same is true of fishes in fresh water. A body of water deprived of all its vegetation, with the associated animals, requires much time for recovery. It is not simply the useful animals that must be taken into consideration, but the entire association of plants and animals.

8. Can correct decisions be reached without investigation of individual cases which arise?

Decisions relative to all the preceding points must usually be reached on the ground. Waters differ in their capacity to neutralize the effects of effluents, in the maximum and minimum

flow, and in their dissolved content. Samples of water should be taken with reference to the particular animal-problem in hand.

9. What is the real value of the waste when the amount of the damage which it causes is added to its commercial value?

One continually hears it said that the recovery of this or that waste product does not pay; this is an all-sufficient reason for not recovering it and the matter is usually dismissed forthwith. We need an entirely new view-point, and a new system of bookkeeping. The value of any waste product is its commercial value, when properly recovered, plus the amount of loss it occasions when unrecovered. Practically all kinds of waste may be made into something useful. Why is it not recovered? I attempted to answer this question when asked by myself of a widely known consulting engineer the other day, by saying that it would not pay. He remarked that, in his experiences, this is not the answer. The manufacturers more often do not care to spend any energy in dealing with the matter. Their object is to do the primary thing in hand and to get rid of the by-products as easily as possible. Here a sense of obligation to act in the interest of the public is needed. It has been estimated that the sewage of ninety-seven cities of more than 50,000 inhabitants, treated by the Miles process, would yield per year as follows:

Fertilizer	97,393,680 tons.
Ammonia	4,869,684 tons.
Grease	25,780,680 tons.
Glycerine	1,289,039 tons.

Recovery plants have not been installed, however, because critics of the conservation plan maintained that the profits will be less than its friends have predicted. As has been true in most other cases, calculations of the cost of suitable recovery plants and of the value of recovered products have probably been made with only minor regard to public health, and with little reference to the damage which the remaining effluent may do to fishes. In correct calculations the value of the recovered products and the benefits to public health would both be regarded as credits. The dangers to fisheries from the residual acid effluent can probably be turned to benefits if sulfur dioxide is used and the residual effluents aerated before being turned into the streams.

Aside from these nine questions which are a basis for the determination of a policy for biologists generally and for fisheries men in particular, the legal situation relative to stream

pollutions is peculiar. In most cases there are adequate laws to prevent the contamination of streams, but when the state goes into court with a complaint the offender usually says, "Tell us how to dispose of our refuse without polluting the streams and we will be glad to do so." He usually is sustained by the court, in continuing the nuisance until the complainant has shown how it can be done. In case of most misdemeanors the offender has to invent his own means of stopping the offense, but, in these cases, the state must discover it for him.

A similar condition is found in the consultation of engineers and biologists. The biologist complains of the ill effects of pollution. The engineer says, "Tell us what must be done to save the fishes and we will do it, otherwise we must ignore them." Here, as in the case of legal matters, the responsibility falls on the biologist, and in a large measure where it belongs, as the final test of all methods of treating or recovering polluting substances lies in the effects of the results on animals. These effects must be determined by experimental study. The time is at hand when fresh-water biologists must perform the experiments, discover the fundamental facts and be able to answer all these questions correctly. For sewage disposal both the Miles and the activated sludge processes afford promising points of attack. The wastage of many industrial residues is likely to be discouraged in future, but there is always something left to be turned into streams and the biologist must be at hand to determine the condition of fisheries and other biological interests in respect to them. Soon public opinion will demand these measures; eventually the battle for the fishes will be won, and when we are advised to eat fish we will be able to find them near at hand.

OUR IRON-CLAD CIVILIZATION

By Professor R. H. WHITBECK

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Meager Resources of Early Centers of Civilization

OUR civilization is inherited from peoples who grew up in Southwestern Asia and the Mediterranean lands, regions singularly destitute of mineral wealth. Here intellectual progress far outran material progress.

The power of thought reached as great a height 2,500 years ago as it has ever attained. The scope of the mind's activities has broadened with the accumulation of knowledge but its creative power is not greater. The masters of to-day write no better literature, think no loftier thoughts, build no nobler buildings than the masters of the ancient world.

The intellectual achievements of man, as distinguished from his material achievements, find expression in the products of thought, in poetry, philosophy, religion, literature. Such attainments, depending mainly upon the creative power of the human mind, are possible in any environment which is friendly to physical and mental vigor. The essential qualities of genius may develop in an environment of meager material resources, as they did in Egypt, Babylonia, Palestine, Phœnicia and still more notably in Greece. In fact, all these centers of human development were in regions relatively poor in natural resources. The flood-plains were agriculturally rich, but Palestine, Phœnicia and Greece were poor. Italy was by no means a rich land.

Material Aspects of Civilization Governed by Kind of Materials Available

But with the material expressions of civilization the situation is different; in each country they are governed by the materials which are available. Such sculpture as Greece produced was possible only in a superlatively gifted people; but sculpture never could attain high perfection in any land where pure white marble was unknown. Marble is found in nearly every country, but marble of such whiteness and texture, such freedom from the slightest flaw, such velvety softness and translucence

of luster was found only in the quarries of Greece. The peerless marble did not produce Greek sculpture—Greek genius did that; the marble simply made it possible. Absolutely no other stone has the combination of qualities which could lure man on to such achievements. The resources included in the geographical environment of a people, or readily obtainable by them, supply the materials in which genius embodies its dreams. If parian marble is a part of the environment, it becomes possible for genius to express itself in sculpture; the environment does not decree that man shall do great things in marble, it decrees only that he may. The environment is permissive, not mandatory.

Stone a Material of Restricted Utility

Man has had to evolve his architecture and make his tools and weapons by using the materials which he could get and could work. Wood, stone and the metals have been the materials at his disposal. Great achievements could not be executed in wood; it is too weak and too perishable. Stone is enduring, but it lends itself to a limited number of uses—mainly buildings and other structures. The Romans, master builders and road makers, accomplished wonders in the one enduring material which they had in abundance—stone. There is no reason to doubt that the Egyptians and the Romans would have done great things in metals if they had had them in sufficient quantities.

Stupendous as are the pyramids, the temples of Karnak or the Great Wall of China; veritable "frozen music" as are the medieval cathedrals, the fact remains that they are passive, stationary objects challenging man's admiration and veneration; they are not mechanisms that multiply his efficiency, his power of production, or his power of further achievement. Had the materials at the service of the human race been only those in kind and quantity which the Mediterranean peoples had at their command, the story of mankind would have been so utterly unlike the story as it is, that it would not seem to be the record of the same world.

Earth's Crust Supplies Only Two Metals in Abundance

Eight chemical elements[1] make up 98 per cent. of the earth's

[1] Oxygen 47.13	Iron 4.71	Sodium 268
Silicon 27.89	Calcium 3.53	Magnesium.2.64
Aluminum ... 8.13	Potassium ...2.35	(Kemp. *Ec. Geol.* 1:699)

crust, but only two of these are metals of sufficient abundance to act as a directing influence in the world's material progress. They are iron, which forms over four and one half per cent. of the crust of the earth, and aluminum which forms over 8 per cent. None of the other metals forms as much as one tenth of one per cent. of the earth's crust.[2] Gold, copper, tin, silver, lead serve many purposes which could not be so well served by any other known substances, yet exhaustion of any one of them would soon be followed by a readjustment which would leave the modern world very much as it is now. Only two metals, then, aluminum and iron, are abundant enough to be really determining factors in directing civilization in its material aspects; and aluminum has not become such a factor, partly because the metal can not be separated cheaply from its most aboundant compounds.

So accustomed have we become to the use of iron and steel for a multitude of uses that it scarcely occurs to us to ask—"Suppose iron had been a rare metal in the crust of the earth, as rare as gold or platinum, what then?" Suppose in the outworking of chemical and geological processes in the earth, iron, because of its high specific gravity, had been confined to the interior of our sphere, far from the reach of man! and suppose gold, or copper, or lead, had been so abundant as to force itself into man's operations in some such way as iron has done! As things have worked out, the material side of our present civilization is notably built up on iron. Iron possesses a marvelous range of possibilities which qualify it to serve a host of purposes which can not be served so well by anything else. From iron or steel are made the revolutionizing mechanisms or machines which have utterly changed the course of human history, mechanisms which in their various parts demand a combination of qualities of strength, elasticity, conductivity, high fusing point, rigidity, weight, or hardness which no other metal possesses.

The Ever-increasing Dominance of Iron and Steel

And so we think, if we take the trouble to consider the matter, "How fortunate that such an indispensable metal is the second most abundant one in the crust of the earth!" Indispensable? Yes, in the sort of civilization which we are born into and which we account to be the best because it is ours.

[2] Certain metals such as calcium, magnesium, sodium and potassium exceed this amount, but they are seldom used except in their compounds and for chemical purposes.

Fairly reliable historical records reach back 6,000 years. The men who built the Great Wall of China or the pyramids, or the Taj Mahal; the men who wrote the epics and chiseled the statuary of Greece; the men who founded the great religions and philosophies that have gripped the world; the men who made the Roman eagles and Roman law and discipline irresistible—carried these aspects of civilization to limits which possibly lie even beyond our attainments in these lines in the twentieth century; yet among these men iron was almost a rarity. Its chief use was for weapons of war.

As a matter of fact, iron has held a commanding position only a century. In 1740 its yearly production, even in Europe, did not exceed two pounds per capita. During the present war, its production reached 800 pounds per capita in the United States. The extensive use of iron is by no means an essential of either a high or a powerful civilization. Yet it is the one thing above everything else which has directed the course and dominated the character of the present epoch on its material side.

Only a Small Fraction of the World has Abundant Iron and Coal

While iron is the second most abundant metal in the crust of the earth, the particular geo-chemical processes by which it has been concentrated in beds of high grade have occurred in relatively few places. Five sixths of the iron ore mined at present comes from small portions of four countries, the United States, Germany, England and France. There are four or five other known areas[2] with valuable deposits. Yet all these deposits, if brought together, could be included within the borders of a small American state. Low grade ores are more abundant. It is a matter of note that, with the single exception of China, none of the highly civilized nations either of antiquity or of the earlier middle ages contained important deposits of iron. It has already been pointed out that our civilization grew up in southwestern Asia and around the Mediterranean, lands poor in iron and still poorer in the fuel for smelting it. It does no violence to realities if we imagine men and nations living on and evolving ever higher planes of civilization in an environment without coal and with but little iron, as they did for thousands of years. The only purpose of thus imagining a condition contrary to fact is that certain conditions which actually

[2] In Brazil, Sweden, China, Russia.

do exist and under which we are living may be seen in their full significance.

A little different outworking of a few chemical and geological processes might have left the iron of the earth's crust widely diffused through the rocks and incapable of extensive use; or a little difference in the history of our planet might have left it, as most parts are left, without coal. But the events that really did happen gave certain parts of the earth coal and iron in enormous quantities, yet left much larger parts with little or none.

The Marvelous Range of Utility Possessed by Iron

The great material developments of modern times have been directed in a remarkable degree by the range of possibilities afforded by the single metal iron, or more strictly speaking, the ferro-alloys. It is an impressive fact that certain of the most significant aspects of progress have been controlled and shaped along a very definite line; it has been progress in the fabrication of iron into tools, machines and engines of ever-widening variety and utility. Starting with the steam engine and progressing through all the marvelous expansion in the designing of machines of every kind, through the growth of means of communication and transportation on land and sea and in the air, means of destruction in war, means of diffusion of knowledge by the printing press, it is evident that the material progress of mankind is running mainly along those lines to which iron and steel have been devoted and to which they are peculiarly suited. There are, of course, scores of contributing factors—chemistry, metallurgy, mechanics, engineering, applications of electricity, and a long list of others—yet at every step these agencies find themselves achieving their conquests with the aid and the indispensable aid of iron and steel.

The Transition from Stone to Steel

Mankind stepped from an era in which his hightest material achievements were in stone structures—to the era of machines which multiply human energy, speed and ability in hundreds of ways. It is the marvelous range of properties that can be imparted to iron by tempering and alloying that make it the incomparable metal. By slightly different methods of treatment or by adding small amounts of carbon, manganese, chromium, nickel, tungsten, or some other element, iron can be given almost any degree of hardness, brittleness, toughness,

elasticity, rigidity or strength, and thus made to meet almost any demand ranging from the hair spring of a watch to an armor-piercing projectile. With such a substance at his command, and easily available in practically unlimited amounts, man has unconsciously come to direct his energies and his inventiveness along lines served by this metal. An age of powerful engines, powerful ships, heavy guns, gigantic dredges, towering buildings, and other things of great weight and strength has come to pass; also an age of labor-performing machines which have given us our present industrial organization of society with all its ills and blessings.

Civilization in its Material Aspects now under a New Control

With coal to supply him energy and with mechanisms that multiplied his power and his producing capacity enormously, the genius of man turned toward a new goal; not art, not architecture, not philosophy—but toward those activities in which the endless adaptations of the machine could best serve him. Master minds now found the opportunity for great achievement in a new field. The age when men of vision embodied their dreams in stone had largely passed. More and more, men of daring, of ability, of energy, saw their rewards lie in a new direction. There was no greater ability or vision than the Athenian possessed; no greater daring or energy than the Roman possessed, but opportunity of a hitherto unknown kind had developed and that opportunity and its reward lay in the activities which we term industry and commerce.

Iron and coal have not made our modern civilization. That is an outgrowth of centuries, molded and shaped by many forces and influences. It is not my desire to minimize any of the other influences which have given modern civilization its character. My purpose is to direct attention to two dominating influences: the influence of the *abundant* metal—iron, and the *abundant* fuel—coal, and to note the effect which the *abundance* of these minerals has had in determining the trend of civilization and in fixing the centers of wealth and of political and military power. The world has come under the domination of the peoples that have great reserves of coal and iron and know how to use them.

THE UPPER CRETACEOUS MISSISSIPPI GULF

By Professor EDWARD W. BERRY
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DURING the vast interval of time that succeeded the deposition of the latest Paleozoic sediments in the southeastern United States—an interval represented by thousands of feet of marine Triassic, Jurassic and Lower Cretaceous sediments in other parts of the world—this region was above the sea and undergoing denudation, slow at times and quickened at other times according as the topography changed.

This old land surface was the scene of the culmination and final extinction of the pteridosperms, ferns, calamites, lepidodendrons and sigillarias that characterized the flora of the coal measures; of the differentiation and final extinction of the fern and gymnosperm floras of the Triassic; and of the expansion and wane of the cycadophytes which were so extensively developed throughout the world during the Jurassic and Lower Cretaceous. Finally it witnessed the origin and differentiation of the angiosperms or flowering plants—the crowning achievement of plant evolution.

True flowers with gaily colored parts are thus, historically, relatively modern achievements of evolutionary activity, largely the result of the stimulus of insect activity in facilitating cross fertilization. Another feature of the flowering plants is their efficiency in the utilization of sunlight for chemical work. Exclusive of bacteria and their relatives none of the lower plant products can compare in their energy with that stored in the seeds of our cereals, nor with but a few exceptions do the lower plants produce fruits.

One is almost tempted to see design in the world-wide radiation of flowering plants during Upper Cretaceous times immediately preceding the Age of Mammals, and it is an impressive fact that but for the development of the fruits and seeds of the flowering plants during the Tertiary period man could not have progressed beyond the carnivorous pack hunting stage of the older Stone Age and civilization would have been an impossible achievement.

The total thickness of marine sediments of the Triassic, Jurassic and Lower Cretaceous of the world, missing in this

area, has been variously considered as amounting to from 12,000 to 40,000 feet and the time involved in their accumulation has been estimated as amounting to at least six million years. This estimate, while it is of necessity far from having an accurate basis, is probably an under rather than an overstatement of the actual time involved.

There is no means for determining how far out on the continental shelf to the southward the coast line extended during these geological periods that are unrepresented by exposed sediments in the southern Appalachian and Eastern Gulf Coastal Plain regions. West of the Mississippi River, however, this geographical history is not an entire blank during this long interval. In the late Jurassic sedimentary records were left in Texas and throughout eastern Mexico, showing that at that time those regions were flooded by the marine waters of the Gulf of Mexico. Again during the Lower Cretaceous the Gulf of Mexico covered much of Mexico, all of Texas and Louisiana, and parts of New Mexico, Oklahoma and Missouri, extending northward into southeastern Arizona and southern Kansas.

Geologists, both in Europe and America, are not in accord regarding the exact time in earth history when the Lower passed into the Upper Cretaceous, although abroad the consensus of opinion seems to be to consider the Cenomanian stage, as it is called, as representing the earliest Upper Cretaceous deposits. In our Western Gulf region, where the Lower Cretaceous is often called the Comanchean system, the later beds referred to the Comanchean—those known as the Washita division—have a wide extent, reaching northward as far as Colorado and central Kansas. These Washita beds carry a marine fauna that is distinctly Cenomanian in type, and the marginal deposits which contain relics of the terrestrial vegetation of that time, as in southern Kansas, furnish a flora that is also distinctly Cenomanian in character. Hence, unless we are to consider that Lower Cretaceous time in this region lasted for thousands of years after Upper Cretaceous time had been inaugurated everywhere else in the world, we are obliged to refer these Washita sediments to the Upper Cretaceous.

The early Upper Cretaceous, or what some students are pleased to call the Mid-Cretaceous, was a time of surpassing interest, not only for the student of earth history, but also for the student of bygone floras. At about this time throughout most coastal regions of the world, the strand commenced one of its periodic invasions of the old land surfaces. Almost

everywhere the resulting initial deposits of this transgressing Upper Cretaceous sea were littoral sands with clay lenses, more or less lignite, and containing fossil plants, but no remains of marine life. Whether it is the Perutz beds of Bohemia, the Gredneria sandstone of Saxony, the Atane beds of Greenland, or the sandstone of Mans in France—the latter locality giving its name to the Cenomanian stage—that are considered, all are lithologically much alike and all contain the remains of floras that are very similar throughout and which furnish many identical species of plants. The extent of the Cenomanian sea in southern North America is shown in Fig. 1.

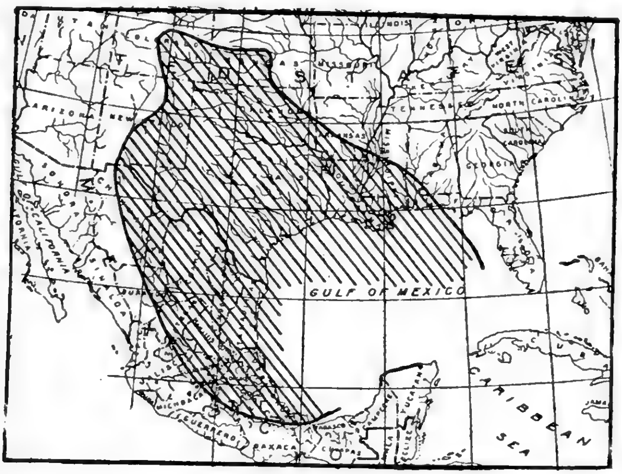

FIG. 1. THE CENOMANIAN SEA (LINED AREA) OF SOUTHERN NORTH AMERICA.

In the lower Mississippi valley and the adjacent country to the eastward we find that the long interval during which the land had been above sea level had resulted in the levelling of the country by the slow processes of erosion until the major portion was covered with the products of rock weathering and the surface was approaching a plain that sloped gently toward the southwest. This old plain is known as the Cumberland peneplain. The streams were mature in character, meandering over broad flood-plains and depositing much of their load of sediments somewhere along their courses.

At this time and possibly inaugurated by some slight warping of the crust, or perhaps caused by the actual rising of the sea level, we commence to see indications in the strata that are available for study, of the approach of the strand across southern Mississippi and southwestern Alabama. The oldest known deposits now visible in this region are referred to what is called

the Tuscaloosa formation. These are found along the southwestern margin of the present Appalachian valley, Cumberland plateau, and the Interior Highlands to the northwest of the Cumberland plateau. They occupy a roughly lunate area convex toward the southwest. This crescent shaped area of Tuscaloosa deposits extends from near Montgomery, Alabama, to the extreme northwestern part of Alabama, and reaches beyond this point as a thin and narrow band of residual sands and gravels northward across Tennessee and Kentucky.

At about the center of this crescent the outcrop of these deposits broadens until it is nearly fifty miles wide. The materials are prevailingly sandy—light-colored, micaceous, irregularly bedded sands with heavy beds of gravel made up of well rounded quartz and subangular chert pebbles. In disconnected and interbedded lenses are laminated or at times massive dark to variegated clays. Some layers are filled with the prostrate logs of drift wood, often of large size; thin bands of lignite are present at various levels, and occasional thin layers are glauconitic sands full of comminuted vegetable débris. No fossil remains have been discovered in these beds except the impressions of land plants and these are usually much broken, presumably because of their having been drifted in river waters. Occasionally more perfect materials are discovered that evidently accumulated in the quiet back water of rivers or in ponds, and that grew near at hand.

The Tuscaloosa formation is usually considered as having a thickness of about 1,000 feet, but this is calculated and not observed. Its basis is the usual method of calculating the thickness of a normal marine formation by the dip of the beds and the width of the outcrop, a method not applicable to the Tuscaloosa since it is obviously not a normal marine deposit. One can not study the Tuscaloosa with its clay lenses, its obliquely crossbedded sands, the abundance of drift wood, prevailing coarseness, widely disseminated vegetable matter, and occasional traces of glauconite, without becoming impressed with its delta-like character. It fulfils all of the requirements of a delta deposit and answers to none of the criteria of a normal marine or estuarine deposit. This obviously does not mean that at its seaward margin it did not merge into littoral, estuarine and lagoonal environments, or that on its landward side it did not extend up the river valleys as fluviatile, lacustrine, and typical continental deposits. All of these types were doubtless being formed contemporaneously and over a long interval of time, that is to be measured by the area over which

this delta-like blanket was spread rather than by the actual thickness of the sediments at any one locality. Formerly estuary conditions were considered as explaining the method of deposition of this and of similar deposits everywhere that lacked marine fossils, but there is usually but slight basis for predicating such an environment. More important were bayous, swamps, sand beaches, lagoons behind barrier beaches, and the various types of continental deposition.

The streams which brought in the sands, driftwood and carbonaceous muds came from the northeast and the bulk of the drainage of the Appalachian interior country, now a part of the Tennessee River system, flowed to the southwest at that time, the delta distributaries being located in the region where the Tuscaloosa formation is found to be thickest and its outcrop widest.

West of the Mississippi River at that time the shallow Cenomanian or Washita sea was having its margins silted up and was gradually withdrawing to the southward, leaving in its wake a mantle of littoral sands that now form a lower part of what is called the Dakota sandstone. The time when this withdrawal of the Washita sea reached its maximum corresponds approximately with the oldest known part of the Tuscaloosa delta or deltas—for there may well have been a series of deltas along this old coast. As seems to be true of all geological history the coast line, so impressive and seemingly permanent a geographical feature, did not remain in a definite position for a long time in the geological sense, but after its withdrawal it commenced a second readvance to the northward, and with this event we reach the time at which we took up the history of the Tuscaloosa delta.

As this sea advanced over the Western Interior region it formed a second mantle of littoral sands that constitute the remainder of what we now know as the Dakota sandstone, which thus becomes progressively younger in its upper portion as it is traced toward the northwest. Overlying these beach sands are normal marine shales which were also being deposited in the south earlier than in the north. The history of this Western Interior sea is beyond the scope of the present article, suffice to say that it eventually became one of the most widespread floodings of the continent that we can trace, and may even have extended until the waters of the Gulf of Mexico mingled with those of the Arctic Ocean. It broadened out medially until its opposite shores were respectively in Idaho and Utah on the west and in Minnesota and Iowa on the east. Its his-

tory was long continued and complicated, and the shores of its prevailingly shallow waters were ever shifting. Concomitant with the advance of this Benton sea as it is called over the Great Plains and Rocky Mountain country we see signs on an incipient embayment extending up the Mississippi Valley.

According to the cosmopolitan terminology of geology this stage of Cretaceous history is known as the Turonian stage from the typical development of its deposits in Touraine, and

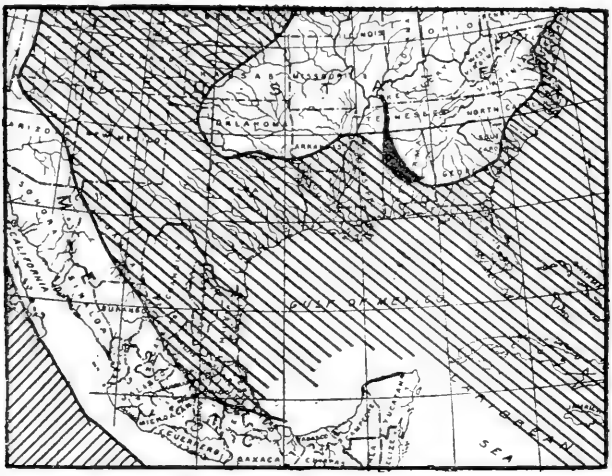

FIG. 2. THE TURONIAN SEA (LINED AREA) OF SOUTHERN NORTH AMERICA.

the geography of that time in southern North America is shown in Fig. 2, the area occupied by the Tuscaloosa delta deposits being indicated by solid black.

The Tuscaloosa delta deposits with their contained fossil flora merge along their seaward margin into marine sands and black laminated clays known as the Eutaw formation, which is then partially contemporaneous with the Tuscaloosa. Higher in the Eutaw occur massive glauconitic and more or less calcareous fossiliferous sands which have been called the Tombigbee sand member of the Eutaw formation because of their development along the Tombigbee River. This sand facies of the Eutaw seems to have been a truly transgressive marine deposit comparable with the Benton of the Western Interior sea. It eventually extended up the Mississippi embayment well across the state of Tennessee. Meanwhile history was not standing still in other regions. The warping of the surface which made it possible for this arm of the sea to extend up the Mississippi valley was naturally not without its effect upon the tributary rivers, and we assume that the Upper Cretaceous

Tennessee River had its southern distributaries silted up and gradually shifted its outlet northward. This can not be demonstrated conclusively, but the fact that the Tuscaloosa sands and gravels can be traced far to the northward along such a probable path, and the fact that these Tuscaloosa sediments in Tennessee are younger than the bulk of the Tuscaloosa deposits farther south as shown by the fossil plants points to such a conclusion. This is rendered still more probable by the additional fact that the upper Eutaw becomes more and more calcareous and finally passes into an argillaceous limestone or calcareous clay of great purity and thickness known as the Selma chalk. In this southern region immediately outside of the lunate area of maximum development of the Tuscaloosa delta deposits and separated from them by only a narrow band of Eutaw deposits there lies a similar lunate area of Selma chalk. Here the latter forms a broad band upwards of 1,000 feet in thickness and continues to the top of the Upper Cretaceous, being immediately overlain by the Eocene. Traced either eastward or northward toward the horns of the crescent the Selma chalk becomes more and more impure until it is replaced along the strike by sands and clays which have received the name of Ripley formation.

The numerous oyster-like and other Mollusca found in the chalk show that it was a shallow water deposit. It contains a very minor percentage of sandy sediments and no drift wood or other land-derived material. The bearing of this is obvious, for if the stream or streams that built the Tuscaloosa delta or deltas still flowed where they had formerly done there would have been no Selma chalk, but these slowly accumulating calcareous muds would have been completely masked by the coarser terrigenous materials brought in by the rivers. Even if a great reduction in run off be postulated, the streams would at least contribute seasonal loads of coarse sediments and the vegetable débris that such slow streams invariably carry would demonstrate their existence by lignitic laminae or by carbonaceous clays in the chalk, and these are not found. The conclusion is inevitable—that at the time the Selma chalk was being deposited the drainage of the eastern shore of the Mississippi embayment was to the northwest and southeast, where the chalk is replaced by sands and not where it had been during Tuscaloosa time.

This northward advance of the Upper Cretaceous sea up the Mississippi valley continued while the Selma chalk was being deposited farther south where its waters were clearer until

finally a broad gulf was formed which reached well into southern Illinois beyond the present mouth of the Ohio, submerging all of Louisiana and Mississippi, western Tennessee and Kentucky, southeastern Missouri, more than half of Arkansas, and the greater part of Texas except the *Llano estacado* region, which then formed a barrier that almost cut off the Mississippi embayment from the Western Interior sea.

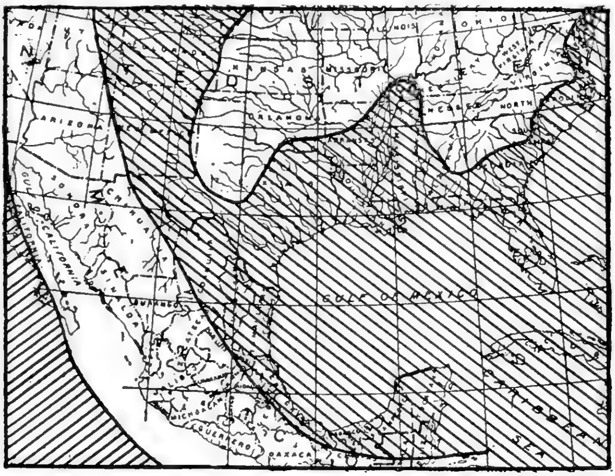

FIG. 3. THE RIPLEY OR EMSCHERIAN SEA (LINED AREA) OF SOUTHERN NORTH AMERICA.

This stage of Cretaceous history is commonly known as the Emscherian or lower Senonian stage, and the geography of that time in southern North America is shown in Fig. 3. This geographical change quite naturally had a profound influence upon the fresh-water inhabitants of the regian, and the striking contrasts between the Naiadaceæ or fresh-water pearl shells of eastern and western North America so pronounced to-day is supposed, whether rightly or wrongly it is hard to say, to date from this invasion of the sea during the Upper Cretaceous.

After this maximum advance of the Gulf of Mexico up the Mississippi valley a recession commenced which is marked by the increasingly near shore and shallow water character of the deposits, with leaf bearing clays deposited in lagoons and estuaries, with many near shore- and mud-loving molluscs like *Corbula.* Only occasionally do we find traces of a normal marine fauna of clearer waters like that found at Owl Creek in Mississippi or along Coon Creek in Tennessee. A limited area in the lower part of the Ripley sands at Coon Creek in the northeastern part of McNairy County, Tennessee, has furnished a

wonderful assemblage of marine fossils. Already it has yielded the remains of three species of fishes, five crabs and nine sea mats (bryozoa), one sea urchin, two worms, one coral and a vast host of mollusca. It has furnished what is probably the most prolific molluscan fauna that has as yet been found anywhere in our American Cretaceous, since about 350 different forms have already been recognized. Gastropods are especially abundant, embracing about 75 genera and 150 species, of which about one third are new to science, and all are beautifully preserved. This fauna contains seven Cephalopods, among which is a veritable giant of a baculite or armored squid. A mounted specimen of one of the more complete of these baculites, but not the largest that has been found, has been mounted in the Johns Hopkins Paleontological collections.

Finally, this region covered by the Upper Cretaceous Mississippi Gulf was entirely drained and remained above the sea for a long interval of time until it was covered once again by a similar transgression of the Gulf of Mexico in lower Eocene (Midway) time. Meanwhile a complex succession of events was taking place in the Western Interior sea. Its shallow marginal waters were repeatedly silted up and converted into coastal swamps in which the luxuriant vegetation of that time went to form the lignitic coals that are so widely distributed in our prairie states. Traces of this sea lingered for a long time in the deeper parts of the basin after most of the area had been transformed into a region of continental and palustrine deposition, and these conditions persisted for a long time after the Mississippi embayment had been drained.

Because of the more favorable conditions for the accumulation and preservation of the remains of the contemporaneous Upper Cretaceous floras, that of the Tuscaloosa is the most extensive and representative of any of the floras of the Upper Cretaceous Mississippi embayment deposits. This Tuscaloosa flora as it is known at the present time comprises over 150 different species, none of which survived in the Eocene of this region. Of the 87 known genera over half are now extinct, while others are no longer represented in North America, but have their surviving descendants in South America, the Orient, or even the antipodes. These 87 genera represent 48 families and 31 orders. The largest alliances are the Ranales (buttercup, custard apple, magnolia order) with 26 different species, the Rosales (rose order) with 15 species, the Sapindales (soapberry order) with 15 species, the Coniferales (conifer order) with 14 species, and the Urticales (fig, bread fruit order) with

8 species. One hundred and twenty-three of the Tuscaloosa forms are dicotyledons, similar to our modern hardwood trees, and of these 107 belong to the more primitive choripetalous division, while only 16 belong to the more specialized gamopetalous division. The largest single genera are *Celastrophyllum, Magnolia* and *Ficus.*

One of the most puzzling of the Tuscaloosa plants is shown in the accompanying figure (Fig. 4). The leaves were digitate and are seen to consist of a central symmetrical terminal leaflet and a pair of inequilateral leaflets on either side of the central one. These leaves are very abundant in the younger beds of the Tuscaloosa toward their seaward margin. It was not difficult to give them a name since they correspond generically with leaves found elsewhere in both Europe and America which were named by Saporta and Marion Dewalquea in honor of the Belgian geologist Dewalque, who first discovered them at Gelinden near Liège. Their botanical relationship, however, has never been satisfactorily determined. Saporta and Marion thought that they were related to the Hellebore tribe of the family Ranunculaceæ, while others consider that they are referable to the Aralia family (Araliaceæ) or the Bombax family (Bombacaceæ). This form, so common in the upper Tuscaloosa, has also been found in Tennessee and South Carolina, and other species are known from Arkansas, Wyoming, New York, New Jersey, North Carolina, Minnesota, Kansas, Belgium, Germany, Bohemia and Greenland, showing that it was evidently a widespread plant type during Upper Cretaceous times.

FIG. 4. LEAF OF *Dewalquea,* an extinct genus of Upper Cretaceous plant, found in the Tuscaloosa delta deposits of Alabama.

An element in the Tuscaloosa as well as in the Eutaw and Ripley floras, one that is no longer found in North America except along the Mexican border is the Cæsalpinaceous genus *Bauhinia,* now confined to the tropical and sub-tropical regions of America, Asia, Africa and Australia. Experience has shown that such modern genera as are represented in all or several tropical regions of the world necessarily have had a long geological ancestry which has enabled them to reach their present

striking confirmation of this theoretical consideration. Upper Cretaceous species, recognized by their very characteristic leaf form, have been found in both Europe and America, and Tertiary species are recorded from southern Europe. About a dozen fossil forms are known and they are especially abundant

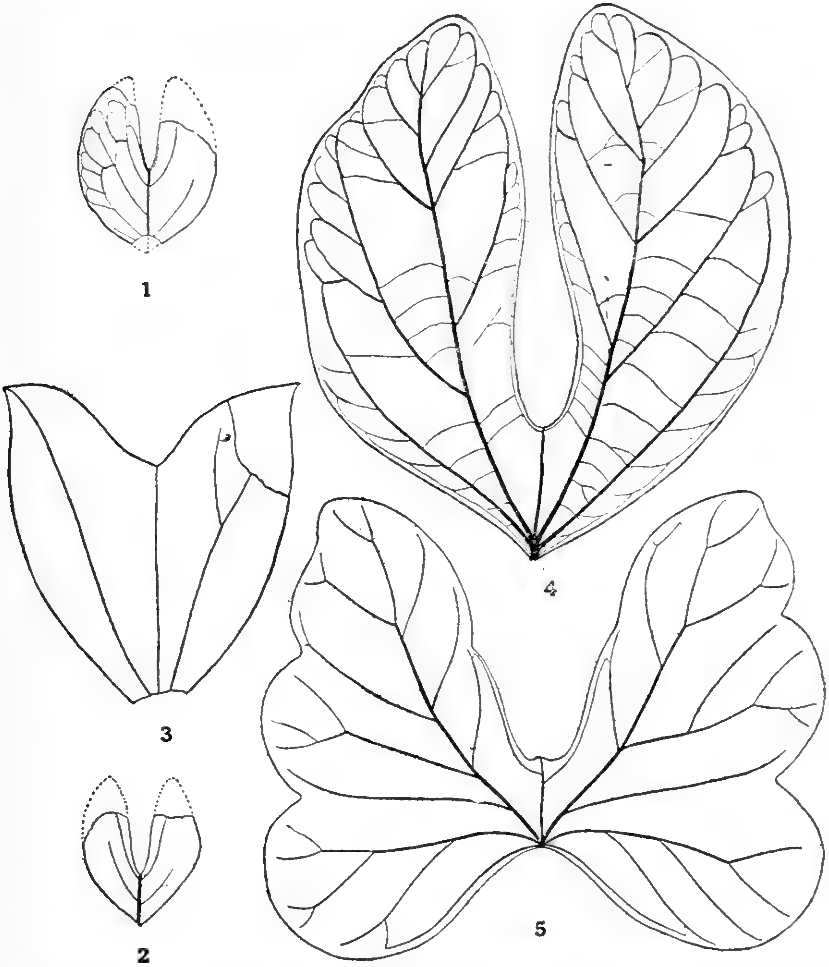

FIG. 5. LEAVES OF VARIOUS UPPER CRETACEOUS BAUHINIAS. 1, 2, *Bauhinia marylandica* Berry from the Magothy formation of Maryland; 3, *Bauhinia ripleyensis* Berry from the Ripley formation of Alabama; 4, *Bauhinia cretacea* Newberry from the Raritan formation of New Jersey; 5, *Bauhinia alabamensis* Berry from the Eutaw formation of Alabama.

and varied in the North American Upper Cretaceous. They seem to have been particularly common during Tuscaloosa time, for at several localities in Alabama leaves of both a large and a small species have been discovered which are also found at

corresponding horizons in Maryland and New Jersey. In the lower Eutaw a large and ornate butterfly-like form has been collected, while a smaller form is present in the Ripley in both Alabama and Tennessee. These are all shown in the accompanying figures.

Another Tuscaloosa plant belonging to the same family as *Bauhinia* and somewhat like it in leaf form is *Hymenæa.* The latter has leathery leaves with a characteristcally different venation and entirely divided to form two inequilateral leaflets. The modern species are trees of the American tropics yielding a variety of copal gum and a hard red wood. They are prized by the South American Indians for their sweetish sour fruits. Not more than eight or ten existing species are known, so they are less than twice as numerous as the known fossil species. In Upper Cretaceous and Tertiary times the genus was represented upon both sides of the Atlantic. Five different forms are recorded from beds of about the same age as those of the Tuscaloosa in Kansas, New Jersey, New York and Bohemia. The Tuscaloosa plant is the handsomest and most clearly defined of any of these.

Several species of *Sequoia* grew round the shores of the Mississippi embayment throughout the Upper Cretaceous, as they had in still earlier times, but the presence of sequoias is not as remarkable as it may seem to the layman who knows only the giant trees and the California redwood of recent times, for sequoias were once cosmopolitan and their foliage or characteristic cones are found in the Mesozoic and Tertiary rocks of most countries where the fossil floras have been studied. There are, however, two other types of Tuscaloosa conifers that deserve special mention.

The first of these is *Dammara* (and *Protodammara*). The modern dammaras or kauri gums comprise several species, mostly insular types, found in the area extending from the Philippines and Malay Peninsula through the East Indies to Fiji and northern New Zealand. They have mostly large, parallel-veined leaves and immense cones of single-seeded deciduous scales. Sometimes in Tertiary rocks, but especially in those of the Upper Cretaceous, kite-shaped mucronate tipped cone scales with longitudinal resin canals have been found. These baffled paleobotanists for a long time, but are now known to be those of *Dammara* and of an allied extinct genus *Protodammara* which had smaller and three-seeded cone scales. Both of these occur in the Tuscaloosa clays as well as in corresponding horizons northward as far as western Greenland and

abodes over land routes no longer in existence. *Bauhinia* is a in Europe. These occurrences prove that this now restricted type of ancient conifer was once common throughout the northern hemisphere and has gradually become restricted to its present limited habitat.

The other Tuscaloosa coniferous type that I wish to mention is *Widdringtonites,* a genus whose descendants are now confined to South Africa and Madagascar with outlying relatives in North Africa, extreme southern South America and Australia. Although foliage like that of *Widdringtonites* is recorded from rocks as old as the late Triassic, it should be remembered that coniferous foliage alone in the absence of cones is difficult to identify with precision, and while *Widdringtonites* has been identified with very many Upper Cretaceous and Tertiary outcrops in North America, Greenland and Europe, they are not all above suspicion. However, if the student is fortunate enough to discover the cones, he can be assured of the nature of his finds, for *Widdringtonites* has characteristic four-valved cones quite distinct from those of other conifers. Among the great abundance of delicate foliage of this plant preserved in the Tuscaloosa clays of Alabama are some with small, attached four-valved cones just like those of the modern forms, thus demonstrating their relationship.

One of the most spectacular members of the Eutaw and Ripley floras is the plant known as *Manihotites georgiana,* shown in the accompanying figure (Fig. 6), one fifteenth natural size. These leaves are subpeltate and of enormous size, deeply lobate and dichotomously sublobate. Naturally, when such large leaves fell into the bayous of Eutaw and Ripley time and drifted out to be buried in the mud of the lagoons, they were almost always broken to pieces, and such fragments are not uncommon and are rather widely distributed, having been found at several localities in North Carolina, Georgia, Tennessee and Arkansas. It would have been entirely impossible to determine their general form or their botanical relationship if it had not been for the accidental discovery by the writer of two nearly perfect leaves in a tiny clay lens in the lower Eutaw sands of western Georgia.

Fig. 6. *Manihotites,* an Upper Cretaceous Cassava leaf from the Eutaw formation of Georgia. × 1/15.

One of these leaves measured 36 centimeters across and the

other 48 centimeters and both apparently came from the same plant. It was at once obvious that they represented an ancestral type of the genus *Manihot*, which includes the Cassava plant, and which has upward of a hundred existing species, nearly all of which are endemic in tropical South America, the majority being found in Brazil. Various of the cultivated varieties will grow in our southern gulf states where the growing season lasts for nearly the whole year, but light frosts or even continued cool weather entirely stops growth. Even in the tropics the best growth is made in the humid coastal regions, so that if the fossil form required a comparable habitat and climate, it furnishes an interesting light on the conditions around the border of the Eutaw and Ripley seas of the Mississippi embayment.

Many other interesting extra-limital types might be mentioned which once flourished in association with the early ancestors of our native trees on the shores of these ancient seas, but enough has perhaps been written to illustrate the fascination in transporting the mind backward through millions of years, forgetful of the obtrusive present, and endeavoring to picture the pulsing life and its environment and the shifting scenes of the geographic history of remote time.

MAN AND HIS NERVOUS SYSTEM IN THE WAR. II

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The General Results of Internal Organization

THROUGH the agency of these various kinds of organization, the activities of the organism are so coordinated or correlated that, under the usual conditions of existence, no one of the life processes outruns the others. No one process or reaction goes on unchecked or uncontrolled, but each process is regulated in conformity with the needs of the body. The organism looks after itself. This orderly coordination of internal activities of the plant or animal organism was, as referred to a few pages back, called physiological integration by Herbert Spencer. The point of view of the physiologist is that all internal processes of the organism go on for the good of the organism as a whole. As Haldane expressed it, the changes which occur in response to changing conditions are such as to perpetuate the life of the organism. This constitutes one phase of what Treviranus called adaptation—the property which, as Burdon-Sanderson believed, distinguishes living from non-living matter.

In setting forth the progress of physiology as consisting in the increase of our knowledge of the internal organization of the plant or animal body, one may see a justification of Burdon-Sanderson's earlier statement as to the proper field of physiology—"The action of the parts or organs in their relation to each other." The physiology of the past has been almost wholly concerned with the physiology of the individual, with only brief reference in a few of the texts, *e. g.*, Beaunis and Luciani, to the physiology of the species.

With the entrance of the physiology of the species into the problem, we must, I think, add something to the statement on the outcome of the processes in living matter. All the ordinary processes in individual living organisms which go on for the good of the organism may be regarded as egoistic activities, or, as some would express it, selfish activities. But when the point of view is shifted from the individual to the species, there is another group of activities which enters in, and which has reference to other individuals. This second group of processes,

since it has reference to other individuals, may be regarded as altruistic rather than egoistic. The continued existence of a species depends, therefore, first upon the successful outcome of the egoistic processes to the end that individual organisms may be present on the earth and, second, upon the successful outcome of the altruistic processes to the end that there may be new individual organisms upon the earth to take the place of those that die. There must be, therefore, a continual balance struck between egoistic and altruistic activities if the species is to survive. To anticipate a part of the discussion in later portions of this paper, we may say, also, that the new individuals must be somewhat better on an average, than the old if evolution is to occur. That evolution has occurred, there is now little doubt.

As a result of the study of the internal organization of living forms, we have gained certain ideas of the various processes or changes occurring in living organisms. Jost[17] summarizes these changes as: (1) Changes of form, including the phenomena of growth and development. (2) Changes of position, either of the organism as a whole or of its parts with relation to each other or to the organism as a whole; this includes all phenomena of movement. (3) Changes of matter and energy—metabolism in its widest sense.

The Organism in Its Environment

Until the organism comes into contact either with its environment or with other organisms, it can have little relation to other things, and, consequently, physiology as a science can have little relation to the great lines of scientific thought in general until it considers the relation of the processes of the regulation of the internal conditions of the organism to the external world. Evolution, heredity and variation, and man's mental reactions to the conditions of his environment are all matters of general biological, or even public, interest and we may inquire into the relation between physiology and these other lines of work. As a rule, the animal physiologist, as distinguished from the plant physiologist, has not considered his material from the point of view of organic evolution, and to a still greater degree, he has not considered how his body of fact will react upon the current conceptions of the process of evolution, either in the way of sharpening our ideas or of modifying them to bring them into line with what is known from the physiological or functional side of biology.

[17] "Vorlesungen über Pflanzenphysiologie," 2d., pp. 3–4, Jena, 1908.

There are certain large problems in biology which, by definition at least, belong to physiology, but which as a matter of fact do not at present form a subject of investigation by physiologists. Such, for instance, are the great questions of development and heredity, and the varied and important reactions between the organism and its environment included under the term ecology or bionomics.[18]

Yet, unquestionably, the body of fact on the functional organization of animals and plants is now sufficiently large and complete to exert an influence upon wider and more general aspects of biological thought.

The Influence of the Doctrine of Evolution upon the Development of Physiology

The doctrine of evolution has had an influence upon the development of the wider inductions of physiology in places where physiology and morphology have touched upon common ground. But the recognition of the influence of organic evolution upon the development of physiology has, on the whole, been more tardy and much less extensive than similar recognition in morphology. The science of morphology is, in fact, confessedly founded upon the doctrine of evolution, but such a statement can not yet be made about physiology. Claude Bernard included evolution as one of the fundamental properties of living matter, and Beaunis included evolution as one of the principles of physiology, but such statements have not been generally incorporated in the texts on physiology in the present century. The biologist must eventually follow the lead of the astronomer or the astrophysicist and the geologist and attempt the explanation of the evolution of plant and animal forms in terms of the underlying changes of matter and energy as the astronomer and the geologist are doing now.

A digression may be pardoned here. Claude Bernard not only saw the larger province of physiology, but he also saw the application of the fundamental principles of science to his own subject. The opinion of a neutral observer from the province of astronomy may be given here:[19]

The statue of Claude Bernard before the college must appeal to every scholar; for his "Introduction a l'étude de la médicine expérimentale," unfortunately veiled from workers in other fields by its medical title, is one of the classics of science. Here in the crystalline clearness of perfect French, devoid, in large part, of professional details, the general principles of scientific research are superbly presented. No investigator unfamiliar with this great work should leave it long unread.

[18] Howell, *loc. cit.*, p. 11.

[19] Hale, G. E., "Science and Learning in France," The Society for American Fellowships in French Universities, p. 11.

There have been times when the physiologist might stand in the presence of his fellows, as Cellini did in the studio of Francis I., and say: "I too am a scientist."

On the morphological side, the idea of evolution has influenced physiology in the development of our ideas of the circulatory, respiratory and digestive mechanisms. Many texts on physiology include brief surveys of the comparative anatomy and physiology of these systems, and there is now in the literature a considerable bulk of facts on the comparative physiology of these systems. But, on the whole, the comparative physiology is treated more from the morphological than the purely functional side.

The influence of evolution is shown also in the treatment of the nervous system. But here again the treatment of the comparative side of the central nervous system has been more morphological than functional. Edinger and von Monakow have shown that, considered morphologically, there are two nervous systems in the higher vertebrates. There is the primitive or phylogenetically older central nervous system to which Edinger has applied the term palæencephalon, present in the lower vertebrates and persisting in higher vertebrates. But higher vertebrates possess some nerve cell groups and fiber tracts which have appeared in the course of organic evolution, and been added to the palæencephalon as it exists in lower vertebrates. This phylogenetically newer portion is known as the neencephalon.

It is the phylogenetically newer portion, the neencephalon of Edinger, which is particularly related to the cerebral hemispheres, either as end stations for afferent fibers or as the site of origin of motor fibers. It follows that cerebral localization is possible in a high degree only when the neencephalon is developed in a high degree. Localization in other parts of the nervous system is probably related more to the palæencephalon than to the neencephalon.

The question of cerebral localization as well as localization in the nervous system generally has been a subject of controversy for more than four decades, and there is still no general agreement on many of the points concerned. There is little question that, morphologically, the anterior portion of the central nervous system—the brain—has undergone profound changes in the course of evolution. Steiner and others have supposed that there might be a shifting of function toward the anterior end of the nervous system corresponding to the change in structure. Gaskell emphasized the increasing importance to

the animal of the head in acquiring its experience. Goltz, however, opposed the idea of the shifting of function toward the brain and denied the validity of the theory of cerebral localization. Goltz stated his belief that the same segments of the nervous system—*i. e.*, the spinal cord, the medulla oblongata, the cerebral hemispheres and the rest—exercised essentially the same functions in all types of animals. There is no detailed and extensive cerebral localization in the frog and, on the basis of Goltz's view, there can be no more in man. Twenty years later, Edinger expressed an essentially similar view about certain portions of the nervous system. I am unable to see the validity of either Goltz's or Edinger's argument, but I have been repeatedly told that the error lies in my own way of thinking and not in any part of the Teutonic argument. I still adhere, however, to my views expressed ten years ago that the function as well as the structure of the central nervous system has undergone profound changes in the course of vertebrate evolution. I do not believe, as Goltz insisted, that the same structures in the nervous system of man necessarily have the same functions they exercise in the frog. Nor do I see that Edinger's view helps us much.[19]

Quite apart from those phases of the subject in which I have come into conflict with the weight of authority, I do not feel that the influence of the idea of evolution upon the general conceptions of physiology has been as great as it should have been.

The Influence of Physiology upon the General Conceptions of Evolution

The other phase of the question remains. What effect have the conceptions of physiology had upon the general trend of thought in evolution?

The contribution made by physiologists directly has not been large, but the application of some of the principles of physiology by biologists to the problems of evolution has been of greater extent. In recent years the plant physiologists have been attacking such problems as the effect of changes in the environment upon plants and we are now getting quantitative data on which to base our opinions. Perhaps a better way to put it is to say that we are supplanting mere opinion by statements of fact.

There is sufficient evidence from the side of physiology to show that there is a decreasing effect of the environment upon

[19] Pike, *Journal of Comparative Neurology*, 1918, XXIX., p. 485.

the internal physico-chemical conditions of organisms as successively higher types are studied. In more recent years it has been recognized that Herbert Spencer made a statement of considerable biological importance when he said the organism acquired an independence of the environment. Woods has emphasized this phase of the subject in "The Law of Diminishing Effect of the Environment" and Julian Huxley has presented the subject, partly from the point of view of the zoologist, partly from the point of view of the philosopher, in his "Individual in the Animal Kingdom." I have given elsewhere a survey of the mechanisms, considered from the point of view of the physiologist, by means of which higher animals have attained their independence of the environment.[20] I have also pointed out that this increasing independence of the environment or, in other words, the increasing rigidity of the internal organization of the organism, eventually leads to a limitation of the possibility of changes in the individual organism in the course of its lifetime.[21] From the lowest forms on up to the highest, there is an increasing rigidity of the physico-chemical organization which not only limits the effect of the environment on the organism, but which also limits the magnitude of internal changes that are compatible with continued life of the organism. Reichert has shown that changes of a physico-chemical nature constitute one of the processes of organic evolution. The conclusion follows, that, while rigidity of the internal physico-chemical organization may result in greater efficiency of the individual organism, it interferes with the progress of evolution in the individual. But Claude Bernard's statement that evolution is one of the characteristics of life seems to me essentially sound. The highly organized, efficient, but unchangeable organism dies and a new one takes its place. Efficiency demands its price.

The data accumulated by physiologists in the study of the chemical mechanisms of the plant and animal body form a necessary background for the study of the dynamic effects of changes in the environment. For until we know the constitution of the organism under standard conditions, we are not in a position to say what changes have been produced in that constitution or physico-chemical system by subjecting it to a different set of conditions.

The chemical mechanisms in the internal organization of

[20] Pike, F. H., and Scott, E. L., *American Naturalist*, 1915, XLIX., p. 321.

[21] *Journal of Heredity*, 1917, VIII., p. 195.

living forms exemplify Bergson's statement that "Life manifests a quest for individuality and tends to constitute systems naturally isolated, naturally closed." For the organism is a physico-chemical system of its own, and it tends to close itself more and more against the effects of the environment. But nowhere does the independence of the environment become complete.

The possibility of the effect of a change in the environment upon the organism is not limited to possibility of an effect upon the physico-chemical mechanisms. Des Cartes, in the seventeenth century, pointed out that the central nervous system is a mechanism capable of bringing about the coordination of the activities of the animal in response to a change in the environment.

The property of irritability is highly developed in nervous tissue, and in the higher animal organisms, we find developed at the periphery an elaborate series of receptors or sense organs whose general function is to lower the threshold of stimulation to a particular form of stimulus, or, in less technical language, to make the organism more sensitive to the manifestations of certain forms of energy in the environment. Some specific examples of these will be given further on in this paper.

Psychologists have taken up the problem of the reaction of the individual to those changes in the environment which affect the sense organs, and to which the individual responds by the exhibition of some phenomenon of behavior. Public interest in their results has been much greater than in the results on the organization of the nervous system, and the influence of the psychologists upon thought has been greater than that of physiologists. The reason for this is that the psychologist has considered the relation of the organism to the environment while the physiologist has not done so to an equal degree. But the fundamental basis for the explanation of the psychologist's results, upon which any rational interpretation of his facts must rest, is the organization of the central nervous system. Progress in psychology is, to this extent, dependent upon progress in the physiology of the nervous system.

It is sometimes a thankless task for a worker in one field to point out the indebtedness of workers in other fields. It is all the more gratifying, therefore, to be able to cite the acknowledgments of other workers of their interest, if not of their indebtedness; for when the acknowledgement is voluntary, the prospects of cooperation are greater, and most certainly the

students of the nervous system need to cooperate in the present state of science. In psychology, there are numerous instances of the manifestation of this interest. A recent example is that of Professor W. H. Burnham whose paper on "The Significance of Stimulation in the Development of the Nervous System"[22] emphasizes the relation of the organism to the environment and gives an account of the organization of the nervous system in terms somewhat different from those which I have employed.

An even stronger statement is that by Forel:

> Comparative Psychology is an as yet almost unexplored territory and but little understood, for want of approaching it by the best side, that is to say, by carefully made observations. It is involved either in metaphysical dogmas, or in shallow anthropomorphism which confounds inherited instinct and its automatisms with the plastic judgment of the individual, based upon memory and the association of memories or sensory impressions. Let us be thoroughly imbued with the truth that each species and even each polymorphic animal form has its special psychology, which should be especially studied, and which depends on the one hand upon the development of its muscles and senses, and on the other upon that of its brain.[23]

I may, then, plead the fundamental nature of the organization of the nervous system as a justification for any attempt to explain man's responses to certain changes in the environment from the point of view of physiology.

It has long been recognized in one way or another that the physiology of the nervous system can not be adequately studied without reference to the relation of the organism to its environment. This is clearly set forth by Professor C. J. Herrick in the opening chapter of his "Introduction to Neurology." Instincts have long had a fascination for biologists and I venture to quote here a statement from a French master which I have cited in another paper.[24]

> We may distinguish, in those attitudes and movements which are intended to express our intellectual and instinctive acts, and which are included under the generic term "gestes," between those which are bound up with organization and, as a consequence, are present in all men, in whatever condition, and those which have arisen and reached their perfection in a social state.
>
> The former are intended to express the most simple condition, the internal sensations as joy, pain, grief and the like, as well as the animal passions, through cries and the voice. One may observe them in the idiot,

[22] *American Journal of Psychology*, 1917, XVIII., p. 38.

[23] "The Senses of Insects," quoted by Rau, Phil and Nellie, "Wasp Studies Afield"; Princeton University Press, 1918.

[24] *Journal of Comparative Neurology*, 1918, XXIX., p. 487.

the savage, the blind from birth, as well as in civilized man enjoying all moral and physical advantages. These are native or instinctive responses.

Whitman[25] also recognized this essential relationship in his statement that "organization shapes behavior."

If, as I hope, I have been successful in showing (1) that physiology has great potentialities for the further study of large biological and human problems and (2) that it has not so far lived up to its promise, I have two things yet to do. We may consider first the reason why physiology has not fulfilled its promises and then make some attempt at the general fulfillment of the promise given in the introduction, to consider man's reaction to the general conditions of the war. As to the reason why physiology has had such a limited development, compared to its opportunities, I suspect German academic influence in great part. The grounds for this suspicion are found in the following quotation from Merz:[26]

> I must remind the reader here that though I use the word biological as denoting the more recent point of view from which all phenomena of the living world are being grouped and comprehended, and though the word seems first to have been used by a German, nevertheless, the arrangement of studies at the German universities has hardly yet recognized the essential unity of all biological sciences. They are unfortunately still divided between the philosophical and the medical faculties. It is indeed an anomaly, hardly consistent with the philosophical and encyclopaedic character of German research, that palaeontology, botany, zoology and anthropology, should belong to the philosophical, whereas anatomy, physiology and pathology are placed in the medical faculty. Eminent biologists and anthropologists, such as Schleiden, Lotze, Helmholtz and Wundt, have accordingly belonged to both faculties. To place biological studies on the right footing would require a mind similar to that of F. A. Wolf, who evolved out of the vaguer idea of humaniora the clearer notion of a science of antiquity, and who accordingly was able to convert the training school of teachers, the seminary, into a nursery of students of antiquity. Whether a similar reform in the purely scientific interests of the "science of life" which is now mostly cultivated for the benefit of the medical practitioner, can be effected in this age when practical aims are gradually taking the place of scientific ideas, is another question.

When we remember the date when this was written (1903) it will be seen that it was not mere war hysteria, but the well-considered opinion of a scholar, arrived at after long and careful study of the problem. For this very reason, it commands more respect and attention than it otherwise might.

The condition which Merz describes does not exist in Germany alone. Physiology, as it has been developed in America,

[25] "Animal Behavior," Marine Biological Lectures, Woods Hole, Session of 1893, p. 298, Boston, 1899.

[26] Vol. 1, p. 220.

largely under the influence of the German schools as I believe, has not concerned itself much with the relation between organism and environment. With little exception, American physiology has been a strictly subordinate subject in a polytechnicum, concerned more with those phases of internal organization which have a supposed immediate medical interest than with those which have a more general scientific interest, and dealing more with those aspects of the relation of the organism to the environment which may be comprised within the limits of the pharmacist's stock of drugs and the appliances of the hospital and the sanitarium than with the relations of organism and environment as they exist in nature generally. The technical aspects of physiology must, of course, be investigated and taught. I am inclined to believe that they should occupy an even larger place in the medical curriculum than they now hold. But these technical aspects should by no means comprise all of physiology. Chemistry and physics long ago passed from the control of medical faculties and began their course of development as independent scientific subjects. It would be interesting to speculate upon their probable present stage of development if they had remained under the exclusive control of either medicine or engineering.

If any insist that there have been no agencies which have tended to retard the progress of physiology, we have still to explain why it has not fulfilled the promise of development which it had in the days of Claude Bernard and the French School of his time. The field has been mapped out and, if there have been no retarding influences, the only alternatives appear to be that a part of the field is unworthy of being worked, or that no men of sufficient vision have appeared to work in all parts of the field, neither of which appears to be wholly reasonable.

The more general phases of physiology are now for the most part being studied in departments of zoology, particularly by the animal ecologists, and botany. The students of the effects of the environment on the organism have been, for the most part, less familiar than they should be, with the details of the internal functional organization of plants and more particularly of animals. The students of internal organization have too often cared but little or not at all for the relation between changes in the environment and possible changes in internal organization. Without the cooperation of workers along each of these lines, and others as well, it does not seem possible that physiology should reach its maximum usefulness to science in

general, and, through science, to the human race. It will not reach its greatest development as a science until more universities establish departments of general physiology, or extend existing departments for the study of the relationships of organism and environment in their widest phases.

It would not, however, be strict justice to German physiology to say, either that all of the tendency toward the restriction of physiology to the narrower field was of German origin, or that no attempts to raise the wider aspects of the science to a plane equalling in popularity and influence that on which the narrower view rests. Verworn, Rosenthal and others, following the leadership of Claude Bernard's classic volume, have presented the subject of general physiology in meritorious texts, and a journal devoted exclusively to general physiology has been published in German for some years past. The relative prominence of the German publications has even led to the neglect of some of the French works on the same subject.

There are indications, however, that the strictly medical side of physiology as it has been taught is no longer quite adequate to the demands of the medicine of the future. Even medical men are beginning to look around beyond the present boundaries of the curriculum. An earlier statement of my own that the physiologist would seem to be the best qualified person finally to decide upon questions of adaptation, and a further statement that the theory of organic evlution seems the best place for workers in every line of biology to bring their results for the inspection and criticism of others, has recently received gratifying support from a medical source. In his volume on the relation of Medicine to Evolution, Adami[27] remarks, that "these matters of adaptation and evolution have of necessity to be approached from the aspect of function and the dynamics of living matter, rather than from the point of view of cell statics." Haldane[28] has considered the relation of the organism to the gaseous environment in detail.

If, as has already been indicated, evolution is one of the properties of living matter, it falls within the province of the physiologist, and its mechanism is to be explained, just as the mechanism of other physiological processes is to be explained, on the fundamental basis of changes of matter and energy. That the task is one of surpassing difficulty, few will doubt, and that we shall quickly arrive at a solution of the problems few

[27] "Medical Contributions to the Study of Evolution," New York, 1918, p. 85.

[28] "Organism and Environment as Illustrated by the Physiology of Breathing," New Haven, 1917.

will hope. The best we can do is to continue work along these lines.

In industrial life too, there is the beginning of an idea that the conditions of work in factories and offices may affect the amount of work done in a day. The human organism becomes a human machine in industrial plants, and it would seem axiomatic that the student of its internal organism should be the one best fitted to study its operation under industrial conditions.[29]

I may here summarize the field of biology, and especially that of physiology by quoting again from the distinguished Briton, Burdon-Sanderson:[30]

> From the short summary of the connection between different parts of our science you will see that biology naturally falls into three divisions, and these are even more sharply distinguished by their methods than by their subjects; namely, Physiology, of which the methods are entirely experimental; Morphology, the science which deals with the forms and structure of plants and animals, and of which it may be said that the body is anatomy, the soul, development; and finally, Oecology, which uses all the knowledge it can obtain from the other two, but chiefly rests on the exploration of the endless varied phenomena of animal and plant life as they manifest themselves under natural conditions. This last branch of biology—the science which concerns itself with the external relations of plants and animals to each other, and to the past and present conditions of their existence, is by far the most attractive. In it those qualities of mind which especially distinguish the naturalist find their highest exercises, and it represents more than any other branch of the subject what Treviranus termed the "Philosophy of living nature."

What is true of animals is true in greater or less measure of Man. We may now pass on to the consideration of man in his relation to his social and political environment.

(*To be continued*)

[29] Lee, F. S., "The Human Machine and Industrial Efficiency," New York, 1918, good bibliography.

[30] *Loc. cit.*, p. 465.

TWO SOUTHERN BOTANISTS AND THE CIVIL WAR

By NEIL E. STEVENS

BUREAU OF PLANT INDUSTRY

A SCIENTIST'S observations often can be best evaluated in the light of a knowledge of the man and the conditions under which he worked. The following notes regarding two eminent American mycologists will then be of interest to botanists; and, in view of the similarities between the times in which they lived and the present, may be of more general interest as showing something of the effect of the Civil War and reconstruction period on the science and the scientists of the south.

The source of the manuscript letters on which the present notes are based is the correspondence of the late Professor Edward Tuckerman, Jr., of Amherst, Mass., fortunately preserved almost complete and now the property of Professor Tuckerman's nephew, Judge E. T. Esty, of Worcester, Mass., who has courteously loaned them to the writer for examination and to whom the writer is much indebted. The correspondence, consisting of over eight hundred letters, dating from 1838 to 1873, is bound in nine quarto volumes and contains letters from practically all the American and many European botanists of that time.

The subjects of this sketch, the Rev. M. A. Curtis and H. W. Ravenel, were both distinguished for their contributions to botany, especially in the field of mycology. They were constant friends and co-laborers and apparently had a voluminous correspondence. At present only their letters to Tuckerman are available. Curtis was a native of Massachusetts, born in Stockbridge and graduated from Williams College. He went to Wilmington, North Carolina, at the age of twenty-two as tutor in the family of Governor Dudley. From this time almost continuously until his death he made his home in the Carolinas. As to his sympathies during the Civil War his correspondence gives not the slightest hint.

Ravenel, on the other hand, was of an old southern family, as he writes Tuckerman in a letter dated "Plantation near Black Oak [S. C.], March 23, 1857."

I have a peculiar love for this section of country—my native place, (here on this very plantation and house, the old family homestead, where I am now writing) and the home of my friends—Here, for six or eight generations, since our Hugenot fathers fled from persecution at the revocation of the Edict of Nantes, have the ties of home attachment been growing and strengthening. . . . The graves of our ancestors are here on these old family seats, and these sacred spots, which had their origin from the rude state of the frontier settlements have been kept up and used with pious care. They constitute, together with the traditionary history of their occupants, an endearing bond with the living, and tend to keep alive a sentiment of filial love and veneration.

It was here on these very plantations which their descendents still continue to occupy, that our ancestors cultivated rice and indigo long anterior to the Revolutionary War. Then, as the scenes of skirmishes and hostile meetings between the contending parties, during "the times that tried men's souls," they have become classic ground to the historian. It was here that the "Swamp Fox" Genl. Marion recruited his brigade, when nearly the whole state was in the hands of the British and tories—and in the wild fastnesses of the Santee swamp, formed a nucleus of hope to the desponding patriots.

It is not then surprising that it is from Ravenel, interested as he was in the history and traditions of his section that we hear the first suggestion of sectional difficulties. He closes a letter written, December 31, 1850, with the following paragraphs:

I have never entertained a doubt that a large portion of the intelligent and patriotic citizens of the North, whatever they may think of our domestic institutions, are disposed to be faithful to the compromises of the constitution and the rights of the States—Could the settlement of this distracting subject be left to them, I would have confidence in the issue—But I fear the decision of the question has passed beyond their power—Demagogueism and fanatacism have swept with demoniac fury over the land, and the voice of reason and patriotism is almost hushed.

The South has loved the Union for the common glories of the past, and for what might have been the common glorious destiny of the future—She has made, and would be willing to make great sacrifices for its preservation—But her honor and self-respect she cannot sacrifice. She has not so learned her lesson of liberty from the great fathers of the republic in the days of its purity—The future is dark and portentious—and I almost despair of the integrity of the Union, but it may be that he who has hitherto so signally blessed and prospered our country may overrule the wicked machination of its foes.

The differences in national opinion which led Ravenel to look upon the future as "dark and portentious" were of course those which arose from the question as to the basis on which California should be admitted to statehood. Difficulties which were temporarily settled by the legislation arising from Clay's historic "Omnibus Bill," a settlement which seems to have

been satisfactory to Ravenel at least, for during the next ten years we find no mention of such matters in his letters.

Letters frequently tell as much by what they omit as by what they include, and it is certainly not without significance that in the score of letters which passed from each of these southerners to their northern friend during the years from 1850 to 1860 there is no mention of political affairs. This is particularly true when it is remembered that this decade was marked by events which were perhaps the most portentious through which this country has passed. Within this time came the birth of the Republican party, with its anti-slavery platform, the disagreements over the enforcement of the fugitive slave law, John Brown's raid, and the bitter struggle for Kansas.

Apparently southern botanists were not interested in politics. Ravenel's last letter, written on October 29, 1859, deals, as had the previous ones, with specimens sent and collections made and with "the preparation of my fifth century of fungi," which he hopes to be able to issue "in the course of a few months." Curtis was even less distracted by events not botanical. Though he is disturbed by the failure of the federal government to give proper attention to mycological collections.[1]

> What a pity that Government does not employ Curators for the preservation and judicious distribution of its collections, instead of leaving them to be eaten by insects, or stolen by unprincipled visitors. There is a large mass of duplicates among the Fungi now in my hands. How are they ever to be distributed properly, without an officer employed for the purpose, and one who has some knowledge of such matters.

On July 16, 1860, he writes asking Tuckerman's help in preparing a complete list of plants for the state geological survey:

> I am preparing, in connection with our Geological Survey, a list of the Plants of this State. I desire to make it as accurate and complete as possible, and that end will be far nearer attained, if I can have your assistance. I send you a list of all the Lichens I know of, belonging to this State, about one-half, I suppose of the actual number. I presume you can add a good many. . . .
>
> My first Report (on the Woody Plants of N. Car.) in a small pamphlet, should be published about this time, and I have ordered a copy to you.

During September, 1860, on the eve of Lincoln's election, Curtis interviews the Governor of North Carolina on a subject far from political and writes his friend Tuckerman as follows:[2]

> Yesterday I had an interview with our Governor, and told him that I

[1] Letter dated March 10, 1859.

[2] Letter dated September 12, 1860.

had rather wait till the end of the current year before making another Report. As he assented to my humor, I can give you an opportunity of adding anything that may come to your notice between this and next December. So, please to consider your Report as *open* till that date for any additions or corrections.

Even later educational and scientific problems seems to have filled his mind, for in October he made a trip to Tennessee, the purpose of which he outlines in a letter dated "Oct. 23d, 1860."

You appear to have inferred that I went westward for "explorations." So far from this, I had no time for them at all, and collected not a solitary specimen except what I now enclose, which I hastily gathered en passant. My journeys westward for the last three or four years (in Aug. 1859 to Tenn; in Feb. last, to N. Orleans, and now again to Tenn.) are in connection with "The University of the South," of which I have been a Trustee from the beginning. The corner stone was laid on the 10th with much ceremony, and in the presence of about 5000 persons.

The closing days of 1860 find our botanists deeply engrossed in their favorite pursuits, Ravenel busy with the preparation of another volume of his Exsiccati and in collecting "likenesses of American and European Botanists"; Curtis at work perfecting his list of plants for the State Geological Survey and urging upon the governor their proper publication; and both all the while sending from the heart of the Carolinas to their friend Tuckerman in abolition Massachusetts, specimens of lichens, personal photographs, notes on plants collected and exchanged, together with delightfully intimate friendly letters full of good wishes and encouragement, and congratulation on his published work.

Here follow five years of silence, broken so far as this correspondence is concerned by only a single southern letter,[3] which is of interest as bringing out the condition of science in the south during the war.

Since the war I have very much fallen behind a respectable knowledge of scientific progress in your department. Scientific pursuits are pretty much suspended in the South now—Minerva, Apollo and the peaceful Deities are driven from our Camps and only Mars remains.

Southern opinions and Southern purposes you will learn from our Newspapers—they do no credit to your Courage or your Conduct. What the result will be, God only knows; but I fear that it will be only the destruction of the best Government in the world and the substitution of the Jiff Davis Dynasty in its stead. Mr. Lincoln's management is wretchedly stupid and inefficient and will end badly, I fear.

The letter just quoted was written March 15, 1863, more

[3] This letter was written to Tuckerman by Thos. Peters, a lawyer and amateur botanist of Moulton, Alabama. He was a friend and correspondent of Curtis, Ravenel, and Tuckerman.

than three months before the battle of Gettysburg. It is probable that Peters's attitude reflects that of many observers, both north and south, as to the probable success of the Confederacy.

Grant and Lee met at Appomattox on April 9, 1865. On August 26, 1865, Ravenel wrote his friend Tuckerman what he characterizes as "the first note written beyond our lines."

> The bloody drama is over—and the four years of carnage is completed! The curtain now rises upon a new scene. What has occurred during these years that we have been shut out from the outside world? Are my old friends with whom I used to converse so agreeably in former times, still in their accustomed place and occupation, or have changes occurred? These and other questions of like import, have made me feel anxious to hear once more from you and others of my former correspondence. Mail communication is now partially resumed, (at least sufficiently so to send a letter through Charleston) and I indite this my first note written beyond our lines to my friend Tuckerman.
>
> Plurimam do Salutem. We are no longer enemies by law, and I send you my greetings.
>
> I cannot know, nor do I ask what your opinions and predelictions have been during the continuance of this bloody struggle. It is over—and its records are made. It has pleased the great Umpire of nations in the order of his Providence, that the Southern Confederacy should not accomplish the object for which they sought. So be it. I accept the issue as from His hands—and am content.

This attitude on Ravenel's part should by no means be taken to indicate that he had not suffered from the war or that he was not a thorough partisan; farther on in the same letter he writes:

> All my sympathies have been for our success. I believed the time had come when our country, overgrown in territory (as I supposed) and with discordant and conflicting interests, would best accomplish its destiny under two separate and independent governments. It has been otherwise ordered by the Great Ruler of nations. I submit without discontent, because I know that infinite wisdom cannot err. I accept the verdict rendered, and in good faith intend to do all that the duties and obligations of a good citizen may require.
>
> . . . .
>
> I have lost all my property, and must henceforth seek some employment for the support of my family.
>
> . . . .
>
> The deplorable state of affairs can scarcely be appreciated. Accustomed as we have been in this new country to abundance of the necessaries of life, we had come to think of destitution and famine as evils only belonging to the old world. The reality has been brought home to us—and many a family who lived in affluence, now scarcely knows from day to day, the means of living.

His poverty was real, for he plans to sell his farm, his books, even his herbarium, and asks Tuckerman to help find a pur-

chaser, but even more eloquently than his words do the poor quality of the paper and especially of the ink which he uses in these letters bespeak the poverty of the man and of his section. The war had evidently forced his favorite pursuit from his attention, and his concluding paragraph contains the remark,

I have done nothing during the war in Botany. Other matters were too absorbing.

War influenced Curtis's studies also, for his first letter to Tuckerman concluded with this paragraph:

During the late war I paid no attention to Botany, except to the edible Mushrooms, from which I have gotten many a substantial and luxurious meal. My experience in this way, and that of several families about me to whom I imparted the knowledge I had acquired, have induced the belief that I might serve the public by a publication of what I know on the subject. Should I succeed in finding a Publisher, I shall be happy to send you a copy.

Evidently botanists have always done their bit in the case of a food shortage.

Reconstruction days were not favorable for the publication of scientific matter. On February 5, 1866, he writes:

My "Mycophagia Americana" hangs fire for the present on account of the enormous cost of publication. Prof. Gray has the thing in hand, and thinks prices will fall after a while, and that I shall have to wait. I have been ready with material these four or five months.

. . . .

P. S. Some five years ago you were kind enough to arrange a list of N. Carolina Lichens for me towards a complete list of the Plants of this State. The war broke out soon after, and the printing of my Reports on the Nat. Hist. of N. Car: was suspended. When it will be resumed I know not. In our present poverty, and with our enormous taxes, I doubt if our present Legislature will give any attention to so insignificant a matter, though I have addressed the Governor on the subject. If it is ever printed, and I mean that it shall be, you shall have a copy of course.

Imagine the feelings of the Governor of North Carolina during the first days of reconstruction being urged to publish a list of plants! The matter is referred to the state legislature which takes the action on this matter of publication that might be expected and a few weeks later Curtis reports:[4]

Since my last, I have recd. a communication from a Committee of our Legislature, proposing that I should publish my Catalogue of N. C. Plants, and a new edition of the "Woody Plants of N. C." on my own account. Our poverty and heavy taxes make the Legislature very chary about burdening the State with even the small amount of such publications. I prefer that the State should do the work; but if it will not, I believe I will run the risk of some loss upon the Catalogue which I am very anxious to have in print.

[4] Letter dated Feb. 22/66.

It is pleasant to be able to record that this list of plants was finally published by the state (1867).

Ravenel's letters from 1866 until the correspondence closes are a record of struggle against the dangers and difficulties of the reconstruction period, the unaccustomed task of earning a living for his family, and most depressing of all a struggle against ill health. On November 8, 1865, he writes:

> With respect to my collections nothing but a sense of necessity would induce me to part with them. I have half relented already in my intentions of selling, and hope the necessity may not arise. We suffered much during the war from privations of all kinds, and especially towards its close—but we endured these hardships, cheerfully hoping for honorable peace to come in time. At its close we found ourselves suddenly brought to poverty,—and our hopes destroyed by its termination so different from what was expected—Still our people were satisfied to accept the issue, and in good faith to abide by the decision against us. We took the oath of allegiance and were prepared to do our duty and fulfill all our obligations as good citizens. It was during the two or three months succeeding the surrender of our army, that the southern people were compelled to pass through the most trying ordeal and to drink the bitter cup of humiliation to its dregs. The military leaders offered us terms which were honorable and which were accepted in good faith. We were prepared to renew our allegiance, and accept the terms which had been offered with the best intentions of forgetting the past and healing old animosities. The terms were repudiated by the civil authorities and we were subjected to military government of the most odious kind. Troops of black savages with arms in their hands were quartered in every town and village, to maltreat and insult us, and to stir up the slaves to revolt and insurrection. Wherever these black troops were sent, they created disaffection among the negroes, and incited them to leave their homes—thus causing vagabondism, idleness, and mischief. They had not been here 12 hours before they had a riot at one of our churches on the Sabbath during prayer hours, the day after that they entered a widow lady's house to insult and abuse her, and on her son's going to headquarters to report the fact, he was knocked down and nearly murdered in hearing of their officers. Ladies were abused and cursed in the streets, and no redress (sufficient to stop such conduct) could be obtained. There was real danger for a while of the negroes being stirred up to acts of bloodshed and murder. These and other atrocities we were compelled to bear without the means of redress and apparently without hope of amelioration. It was then that I wished to leave the country and go anywhere, where law and order prevailed. I am glad to say that a much better state of things now prevails. The military authorities have removed the black troops, and the negroes are quiet and orderly.

And again in March, 1866, he exclaims:

> We are charged with disloyal feelings and with a desire to oppress the freedmen unless restrained. There is positively no truth in either of these charges. Our people have with most wonderful unanimity, accepted the issues of the war as final and irreversible. They struggled manfully for four years and put forth their entire strength and resources in the fight,

because they conscientiously believed they were battling in the cause of Civil Liberty for a great principle, the right of Self Government. The fortunes of war have been decided against them. They failed after all their efforts for independence, and now as a law-abiding people who have been trained in the school of constitutional government, they are willing to abide by the issue in good faith and give their allegiance to the govt which protects them and under which they are to live. I am sure that 99 per cent of our people hold these views. That there still continues to exist in some quarters, ill feelings toward the Govt.—that the sense of injuries and of suffering should still linger in some breasts—that is only what we might expect. It would be miraculous, were it otherwise, so long as human nature remains as it is. But with the great mass of the people, these feelings do not exist—and their existence in the few can do no harm. They will gradually disappear under the healing influence of time. A great nation victorious and triumphant everywhere, without a solitary foe to dispute her power, may well exercise clemency in dealing with the harmless vagaries of a few discontented spirits.

Yet such is his friendship for Tuckerman that he is able to write in the same letter:

Your last letter received some time ago, gave me much pleasure. I have not replied sooner simply because there was nothing especially to call for a reply except to tell you how highly I appreciate the kind feelings evinced towards me personally—and the very liberal and Christian spirit in which you regard the late national chastisements.

During 1867 there are no letters, but on January 12, 1868, he "interrupts the silence" with "A New Year's Greeting" and adds:

I would like to hear once more from you. Your letters are always welcome, instructive and interesting. They remind me of the times when I was more engaged in botany than I am now, or can ever hope to be again. I have now at least the satisfaction of these pleasant reminiscences, and the hope that my labors may have contributed somewhat to botanical science. What have you accomplished in the year passed? And what progress is made in your work on N. Am. Lichens. I suppose your Exsiccati is not yet out or I should have heard from you.

Please give me a line and tell me of your labors. I am still interested in botany though I can very little afford any time for its pursuit. It is now a struggle for subsistence.

During the next month he refers more at length to his poverty and that of his section. (Letter dated Feb. 21st, 1868.)

You say "you trust I am not weaned from botany." I still linger on the outskirts (as it were)—but am compelled from necessity to do whatever comes to my hand, to get my daily bread. I suppose you can form but a faint idea of the universal destitution prevailing throughout the Southern States. All are in poverty. . . . No capital will venture here while this state of things continues—and there is nothing left to our own people to begin the work of rebuilding their broken fortunes. . . . I feel like a shipwrecked mariner who has been cast upon a desert coast, and forced

to subsist on whatever may be washed ashore and on the crude sustenance to be found at hand. . . . I once had a sufficiency to follow my inclinations, and *avoid* the tracks of trade. . . . I get a comfortable living (by using great economy) in selling vegetables from my garden and doing a little wood cutting for the railroad, disposing of such books as I can best spare and occasionally selling one of my botanical collections (those collected for the purpose of sale.) I have not touched my herbarium and intend to hold on to that. . . . Do not understand me as murmuring, or complaining of my lot. It is only that of thousands of others. Indeed I have daily cause of thankfulness to a kind Providence which has so signally blessed me. With my large family (10) in number) to provide for, I cannot avoid at times feeling anxiety. . . . Excuse me for dwelling too much upon matters which are painful to hear of. They occupy so much of my thoughts that they find expression but too readily. I always train myself to look at the cheerful side,—and am still in hopes that the dark clouds that overhang us, will soon pass away. At any rate, we *know* that the sun still shines beyond, and that in good time its genial rays will enliven and bless our land.

Scattered letters through 1869 mention a continued interest and, so far as circumstances permitted, activity in the botanical field. During the early months of 1870 he seems to have rendered Tuckerman considerable assistance by sending specimens of southern lichens, but under what difficulties is shown by two letters written during March.[5]

I have been occupying myself lately in making up sets of Lichens which I shall dispose of. I am under the necessity of doing this or else abandoning Botany altogether and seeking some other occupation that will give me a living.

You must excuse me if I send you the same things over under different names,—and some of which ought to be familiar to me. I have scarcely opened my Vol. of Lichens in the last 12 or 15 years,—and this last sad decade has mostly driven my thoughts from botany. And moreover I have parted with my microscope, and though I have the use of it whenever I want, I find the powers are not high enough for a satisfactory examination—(the smaller lens being *worn out*) and there are so many of the new species not yet described that I am often perplexed how to decide. . . . In making up my sets for sale, I think two good objects may be accomplished—one to furnish me with a little addition to my scanty means—and the other to enable those who are interested in the study to obtain our Southern Lichens.

Throughout the difficult years following the war, his love of botanical study and his friendship for Tuckerman seems to have remained among Ravenel's chief pleasures. His last important letter to Tuckerman (written May 3, 1870) concludes with the following paragraph:

My chief converse and entertainment is with my correspondents, who like yourself and one or two others, have been rambling the same pathway

[5] Letters dated March 2 and March 22, 1870.

of life for now a quarter of a century. To me, the reminiscences of these earlier pursuits are exceedingly pleasant,—and a long and uninterrupted friendly intercourse, give additional strength to the bonds of a friendship established on common pursuits and sympathies. These are the things which make the retrospect of life grateful to us—and nerve us to higher aims and objects.—The asperities of political strife trouble me but little. I try to live in an atmosphere above them and to look on all these movements as the trickery of the political.

The scientists of to-day face a reconstruction period in international affairs perhaps no less trying than were those of 1865 to '70 in national affairs. It is possible that now as in '65 "the first note written beyond our lines" will come from scientists recently counted as "enemy," but who before the war were in close touch with this country. And it is to be expected that American answers will be such that correspondents will with Ravenel "appreciate the kind feelings evinced toward them personally,—and the very liberal spirit" in which we regard the late international chastisements.

WILLIAM RAMSAY

By BENJAMIN HARROW, Ph.D.

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IN that elegant tribute to Ramsay, written in the days when comradeship between the scientists of England and Germany was close, Ostwald summarizes him as one belonging to the romantic type in science. Romantic he was, for his imagination was unlimited. The secret of Ramsay's great triumphs lay in the fact that with this imagination there was a well-balanced knowledge of the science, with a seer's insight into the significance of its laws. Bold in the conception of a problem, he was brilliant beyond comparison in its execution. With no fetish to hold him, with the mantle of the prophet about him, and with amazing manipulative skill, he laid bare, in rapid succession, a regular little battalion of new gases in the atmosphere, followed by transmutation experiments which made the scientific world gasp and hold its breath in expectancy of the next dare-devil leap.

This genius, born in Glasgow in 1852, did not spring from any geniuses, but, like many another man of talent, his stock was of a fairly ordinary type. To be sure, there was an uncle with a reputation as a geologist, and the father had some scientific tastes, but nothing at all to warrant such outpourings in the offspring. When eleven years old he joined the Third Latin Class of the Glasgow Academy, and during the three succeeding years at the institution he did little Latin, gained no prizes, and did much dreaming. Ramsay describes himself in a short autobiography as "to a certain extent precocious, though idle and dreamy youngster." This fits in with Ostwald's theory of the genius: "The precociousness is a practically universal phenomenon of incipient genius, and the dreamy quality indicates that original production of thought which lies at the basis of all creative activity." Even thus early he evinced a passion for languages, for it is recorded that during sermon time at church he read the French and German texts of the Bible and translated them into English. In after years, as president of an international scientific gathering, he would astound the assembly by addressing them successively in French, German and Italian.

His introduction to chemistry came in quite an unexpected way. A football skirmish resulted in his breaking a leg, and to lessen the monotony of convalescence, Ramsay read Graham's "Chemistry," with the object, as he frankly confesses, of learning how to make fireworks. During the next four years his bedroom was full of bottles and test-tubes, and often full of strange odors and of startling noises. But systematic chemistry was not taken up till 1869, three years after he had entered the University of Glasgow. Then, it seems, the passion came on, and with it, a passion for the cognate science, physics. This resulted in an introduction to William Thompson (later Lord Kelvin), the then professor, who set the youngster upon the elevating task of getting the "kinks" out of a bundle of copper wire, an operation which lasted a week. It is to be presumed that Thompson was favorably impressed with the manner in which this piece of research was carried out, for Ramsay was immediately introduced to a quadrant electrometer and asked to study its construction and use.

A year's introductory study of chemistry decided Ramsay upon his career, and with his parents' blessing he set out for Heidelberg in 1870, to be exchanged for Tübingen some months later. In Tübingen ruled Fittig, whose lectures were "distinct and clear," whose scholarship was sound, and whose research was methodical. The two years spent at Tübingen were full of work and no play. "I was up this morning," he writes to his father "at 5.30 and studied and took my breakfast from 6 to 7,—a class from 7 to 8, one from 8 to 9, and 9 to 3 laboratory (I lunch now to have more time for work, and don't dine till 6), and from 3 to 5 I studied, then from 5 to 6 lecture, and then I dined. And now at 8 I must start again." And so this was kept up—all the time, curiously enough, with emphasis on organic chemistry, a branch of the science which Ramsay almost wholly abandoned in his later and most productive years—till the time for the Ph.D. examination. "On Monday at 7 it began and lasted till half-past 12; then in the afternoon from 3 to 8, so we had a good spell of it." The questions in chemistry were: (*a*) the resemblances and differences between the compounds of carbon and silicon, and (*b*) the relation between glycerine and its newer derivatives and the other compounds containing three atoms of carbon; in physics: (*a*) the different methods for determining the specific gravity of gases and vapors, and (*b*) the phenomena which may be observed in crystals in polarized light.

I managed to answer the first perfectly, the second, however, not so well, and the two questions in physics pretty well. Then to-night we had the oral exam. The five professors who compose the faculty were there. Fittig gave some very difficult questions. Reusch (physics), on the other hand, very easy ones. . . . We had to dress up and put on white kids, and I had to get a "tile" especially for the occasion. Then we were sent out after the exam. for about five minutes and were then called in and formally told we had passed.

A dissertation on "toluic and nitrotoluic acids," which gave no glimpse of the future before him, completed Ramsay's Ph.D. requirements, and he returned to Glasgow, where he became assistant in the Young Laboratory of Technical Chemistry. And now Ramsay had to turn his attention from organic to inorganic chemistry, for most of the courses at the technical school were devoted to the latter. Though the physico-chemistry background was entirely lacking, and therefore the knowledge obtained could hardly have been more than miscellaneous, innumerable facts were picked up and stored for future reference. An opening as tutorial assistant at Glasgow University offered the possibilities of a more congenial academic atmosphere, and also the hope of continuing his interrupted research in organic chemistry.

The cellars of the University Laboratory contained a large collection of fractions of "Dippel-Oil" prepared by Professor Thomas Anderson. These were regarded by Ferguson (his successor), whose interest in Chemistry was almost entirely that of an antiquary, more or less in the light of museum specimens, and he was horrified when Ramsay suggested that he should be allowed to "investigate" them, but he eventually gave way to Ramsay's importunity. The result was a very substantial addition to our knowledge of the pyridine bases and their derivatives.[2]

The chemistry of dyes and explosives was not to be his life work. How he turned from this to the more mathematical branch of the subject is ascribed by Ramsay himself to problems he encountered in attempts to determine the molecular weights of some of his organic compounds by the Victor Meyer vapor density method. But we must also add that Ramsay, with that instinct for detecting the truly important among a mass of new theories and facts, which was one of his greatest assets, early foresaw the part the new science of physical chemistry would play in the development of chemistry. Thus he was one of the earliest in England to appreciate the true significance of Guldberg and Waage's "law of mass action," just as, at a later date, he was among the first to seize upon and translate Van't Hoff's celebrated paper on the analogy between

[2] "Sir James Dobbie" (68), p. 48.

the state of substance in solution and the same when in a state of gas. The Victor Meyer method suggested to him experiments on the volume of liquids at their boiling point, and this in turn gave rise to a whole series of new possibilities, the experimental side of which kept him and his collaborators, particularly Young and Shields, busy even after he had settled in University College years later.[3]

For six years Ramsay remained assistant at Glasgow University, and though during that time he had been a candidate for several chairs and lectureships, nothing came of any of them. So discouraged did he become that there was much discussion in the family as to the advisability of starting business as a chemical manufacturer. But before this scheme could be put into execution a vacancy at University College, Bristol, presented itself. The story goes that his knowledge of Dutch saved the day. According to this account one of the members of the university council, a minister, was much perplexed with a Dutch text in his possession, and Ramsay volunteered a translation. The result was Ramsay's appointment by a majority of one. The stipend was fixed at a minimum of £400 ($2,000) per year. The contract read:

> The professor will be required to give three lectures per week for the first two terms, say 60 lectures, together with class instruction in connection therewith . . . and a short course of lectures in the third term. He will also be required to superintend the laboratory during the whole session, and to give evening lectures once a week during the first two terms, together with class instruction in connection therewith. . . . The scheme of the college contemplates the possibility of occasional lectures being delivered in neighboring towns by the Professor or his assistant. . . . In connection with the Cloth working Industry, special instruction in dyeing, etc., may be required under an arrangement not yet concluded with the worshipful the Cloth-workers' Company of London.

The professor, not yet turned thirty, was to be kept busy on the job, with very little opportunity for research—an altogether minor consideration to the worthy councillors. But they had not reckoned on Ramsay's energy and capacity. Determinations of the density of gases, of the specific volumes of liquids at their boiling point, of the vapor pressures and critical constants of liquids were soon in full blast. And then came those

[3] It was while blowing the bulbs used in this research (the volumes of liquids at their boiling point), I believe, that he first became aware of the asset he possessed for physical work in his skill as a glass-blower. He had learnt the art at Tübingen, although it was only in his later researches that his marvellous manipulative power was fully developed.—Sir James Dobbie.

classical determinations on the thermal properties of solids and liquids, and on evaporation and dissociation, most of which was done with his assistant, Young, which continued at full blast for the next five years until Ramsay's transfer to London. This appointment came in 1887. By that time Ramsay's reputation was such that the following year he was elected an F.R.S. (Fellow of the Royal Society).

In London his physico-chemical researches were further extended. Among these particular mention should be made of perhaps the most brilliant of them all—the measurement of surface tension up to the critical temperature, which led to the well-known law supplying us with a method for determining the molecular weight of liquids. Here Ramsay had an able assistant in Shields.

In 1890 the British Association met at Leeds, and two of the great continental founders of modern physical chemistry, Van't Hoff and Ostwald, were present. Ramsay, who represented the school in England, naturally took a keen interest in this meeting.

> Ramsay and Ostwald met for the first time as fellow-guests in my house, which became accordingly a sort of cyclonic center of the polemical storm that raged during the whole week. . . . The discussion was incessant. . . . I remember conducting a party to Fountains Abbey on the Saturday and hearing nothing but talk of the ionic theory amid the beauties of Studley Royal. The climax, however, was reached the next day, Sunday. The discussion began at luncheon when Fitzgerald raised the question of the molecular integrity of the salt in the soup and walked round the table with a diagram to confound Van't Hoff and Ostwald. . . . Ramsay was no silent spectator. Being a convinced ionist, he was eager in helping out the expositions of Ostwald, whose English at that time was imperfect and explosive, and his wit and humor played over the whole proceedings. . . . It was the beginning of relations of great mutual sympathy and regard between Ramsay and Ostwald, which lasted till they were divided by their respective national sympathies at the unhappy outbreak of war.[4]

And now we come to a momentous event in the career of our hero. Lord Raleigh had for some time been engaged in determinations of the exact densities of a number of gases. Among these was nitrogen. In his experiments Raleigh found that the density of nitrogen obtained from the air was slightly but consistently higher than that obtained from artificial sources. Writing to *Nature* (1892) he says:

> I am much puzzled by some results as to the density of nitrogen and shall be obliged if any of your chemical readers can offer suggestions as

[4] Professor Smithells.

to the cause. According to two methods of preparation I obtain quite distinct values. The relative difference, amounting to about 1/1,000th part, is small in itself; but it lies entirely outside the errors of experiment.

The difference in the weights of one liter of the gas obtained in the one case from atmospheric air and in the other from ammonia varied by about 6 in 1,200, or about 0.5 per cent., but the accuracy of the method did not involve an error of more than 0.02 per cent.

With that keen scent for any promising material Ramsay immediately took up the problem. Some years previously he had found that nitrogen is absorbed fairly readily by magnesium. This suggested to him that by first getting rid of the oxygen in the air, and passing the remaining nitrogen repeatedly over heated magnesium, any other gas that might possibly be present in the atmosphere would remain unabsorbed. This unabsorbed gas was isolated and found to give a characteristic spectrum. The name *argon* was given to the newly discovered ingredient of the atmosphere. It proved to be more refractory than the comparatively inert nitrogen: it just simply would not make friends and combine with any other element!

Shortly after this Ramsay's attention was called to some experiments of Hillebrand, of the U. S. Geological Survey, in which he obtained a gas believed to be nitrogen from certain minerals, particularly one called clevite, but which was now suspected to contain argon as well. Ramsay lost no time. From it he obtained argon, to be sure, but also another gas, with a spectrum all its own, which showed it to be identical with an element present in the chromosphere of the sun, and which until then had been considered peculiar to the sun. Lockyer years ago gave the name "helium" to it, and now Ramsay had rediscovered it on mother earth. But let the discoverer tell the exciting news. On the 24th of March, 1895, he writes to his wife:[5]

Let's take the biggest piece of news first. I bottled the new gas in a vacuum tube, and arranged so that I could see its spectrum and that of argon in the same spectroscope at the same time. There is argon in the gas; but there was a magnificent yellow line, brilliantly bright, not coin-

[5] Ramsay married Margaret, daughter of George Stevenson Buchanan, in August, 1881, soon after he had been appointed principal of Bristol College—a position he attained one year after his arrival in Bristol. This union proved a particularly happy one. "To have such a helpmate as my wife has brought me happiness which I must acknowledge with the greatest thankfulness." And at a later date he wrote to a friend: "You have got a good son and daughter and that is much to rejoice at. So have I."

cident with but very close to the sodium yellow line. I was puzzled, but began to smell a rat. I told Crookes,[6] and on Saturday morning when Harley, Shields,[7] and I were looking at the spectrum in the dark room a telegram came from Crookes. He had sent a copy here[8] and I enclose that copy. You may wonder what it means. Helium is the name given to a line in the solar spectrum, known to belong to an element, but that element has hitherto been unknown on earth. . . . It is quite overwhelming and beats argon. I telegraphed to Berthelot[9] at once yesterday—"Gaz obtenu par moi clevite mélange argon helium. Crookes identifie spectre. Faites communication Académie lundi.—Ramsay." . . . I have written Lord Rayleigh and I'll send a note to the R.S. (Royal Society) to-morrow. . . .

The first public account of helium was given to a semi-bewildered audience at the annual meeting of the Chemical Society, 1895, on the occasion of the presentation of the Faraday medal to Lord Raleigh. Further investigations proved that helium was not only a terrestrial element, but also occurred in quite a number of minerals and mineral waters. To Kayser, however, was left the proof of its presence in the air. Like argon it simply refused to combine with any other substance.

To the ancients air was a source of investigation, and it had remained so. Till 1894 no one, least of all a scientist,[10] would have suspected the existence in the atmosphere of undiscovered elements. Ramsay and Raleigh's discovery shook the scientific world. Recognition came from all parts. Lord Kelvin, as president of the Royal Society, presented Ramsay with the Davy Medal, with the following comment:

. . . The researches on which the award of the Davy Medal to Professor Ramsay is chiefly founded are, firstly, those which he has carried on, in conjunction with Lord Raleigh, in the investigation of the properties of argon, and in the discovery of unproved and rapid methods of getting it from the atmosphere; and secondly, the discovery in certain rare minerals, of a new elementary gas which appears to be identical with the hitherto hypothetical solar element, to which Mr. Lockyer many years ago gave the name of "helium." . . . The conferring of the Davy Medal on Professor Ramsay is a crowning act of recognition of his work on argon and helium which has already been recognised as worthy of honor by scientific societies in other countries. For his discoveries of these gases he has already been awarded the Foreign Membership of the Société Philosophique de Genève and of the Leyden Philosophical Society. He has had the Barnard Medal of Columbia College awarded to him by the American Academy of Sciences, and within the last few weeks he has been elected a Foreign Correspondent of the French Académie des Sciences.

[6] Sir William Crookes, the famous physicist.
[7] His two assistants.
[8] 12 Arundel Gardens, their home.
[9] A famous French chemist.
[10] Cavendish, in 1785, did suspect some such possibility.

Such was the excitement aroused by these discoveries that even young students were filled with the epidemic. We are told that "answers to examination questions showed that oxygen as a constituent of our air was almost forgotten in the anxiety on the part of the candidate to show that he or she knew all about argon." But Ramsay had not yet sufficiently dumfounded his scientific confrères. From a careful study of Mendeleeff's periodic grouping of the elements he came to the conclusion that another inert gas ought to exist between helium and argon, employing a process of reasoning quite analogous to one used by the celebrated Russian many years before when, with the help of his periodic table, he predicted the discovery of new elements. Ramsay ransacked every possible source for this new element: minerals from all parts of the globe, mineral waters from Britain, France and Iceland; meteorites from interstellar space—all without result. A clue was at length obtained when he found that by diffusion argon could be separated into a lighter and heavier portion. This suggested the presence of the unknown gas as an impurity in argon. It was evident that the unknown gas, if present, could be there in minute quantities only to have escaped detection. That meant that the larger the quantity of argon employed the better the possibilities of getting appreciable quantities of the unknown constituent.

A simple method of separating the constituents in a mixture of liquids is to boil the mixture, and collect fractions of the condensed vapor. Each constituent will usually go off at a fairly definite temperature. This, in principle, was the method employed by Ramsay and his assistant, Travers. They prepared, to begin with, no less than fifteen liters of *liquid* argon!

> On distilling liquid argon, the first portions of the gas to boil off were found to be lighter than argon; and on allowing the liquid air to boil off slowly, heavier gases came off at last. It was easy to recognise these gases by help of the spectroscope, for the light gas, to which we gave the name *neon* or "the new one," when electrically excited emits a brilliant flame colored light; and one of the heavy gases, which we called *Krypton* or "the hidden one," is characterised by two brilliant lines, one in the yellow and one in the green part of the spectrum. The third gas, named *xenon* or "the stranger" gives out a greenish-blue light, and is remarkable for a very complex spectrum in which blue lines are conspicuous.

A trio, neon, xenon, krypton, added to helium and argon—making five new gases—and all in the atmosphere!

Further recognition came from the Chemical Society of London. They awarded Ramsay the Longstaff medal, given

triennially to the Fellow of the Chemical Society who, in the opinion of the Council, has done the most to promote chemical science by research. "If I may say a word of disparagement," added Mr. Vernon Harcourt, the president, in presenting the medal, "it is,"—and here we can see the twinkle in his eye—"that these elements (argon, helium, etc.) are hardly worthy of the position in which they are placed. If other elements were of the same unsociable character chemistry would not exist."

Ramsay's studies on helium led him to ponder over this question: why is helium only found in minerals which contain uranium and thorium—substances which give rise to radio-active phenomena? Attempts to answer this led him into the field of radio-activity, with results which even surpassed his investigations on the inert gases of the atmosphere. In 1903, in conjunction with Soddy, he succeeded in proving that helium, an element, could be produced from radium, another element. The transmutation of the elements come to life again! Those poor, foolish old alchemists, we were always led to believe, wasted their lives in vain attempts to transmute the baser metals into gold. And here comes the dashing Ramsay, bold, as usual, to audacity, and calmly announces that *his* experiments prove the alchemists not to have been such fools after all! Succeeding experiments on the action of radium salts on copper and lead solutions led Ramsay to believe that copper and lead can undergo disintegration into sodium and lithium, respectively—two entirely different elements! These latter claims still wait to be verified, but there is reasonable hope for assuming that various experimenters throughout the world will soon undertake the task of carefully repeating the entire work, now that peace is once again with us.

A fitting award for these achievements was the bestowal of the Nobel Prize to Ramsay in 1904. The distribution of the prizes took place in Stockholm on December 10 of that year, in the presence of King Oscar and the royal family, foreign ministers and members of the cabinet, and many leading representatives of science, art and literature. After speeches had been delivered by the vice-president and other representatives of the Nobel Committee, and of the academies of science, medicine and literature, King Oscar personally presented Lord Rayleigh (prize winner in physics), Sir William Ramsay[11] (chemistry) and Professor Pavlov (physiology) with their prizes, together

[11] Ramsay had been created a Knight Commander of the Bath (K.C.B.) in 1902, which carried with it the title of "Sir."

with diplomas and gold medals.[12] The distribution of the prizes was followed by a banquet, at which the Crown Prince presided. Count Morner proposed the health of Professor Pavloff, Professor Petterson that of Sir William Ramsay, and Professor Hasselberg that of Lord Rayleigh. The following day Ramsay delivered a lecture on argon and helium at the Academy of Sciences, which was followed by a dinner given in his honor by King Oscar. Writing from Switzerland to a friend some weeks later Ramsay says:

> We had a most gorgeous time for nearly a week, dining with all the celebrities, including old King Oscar. The old gentleman was very kindly and took Lord R. and me into his private room and showed us all his curiosities, the portraits of his sons when they were children and his reliques of Gustavus Adolphus and of Charles XII. The Crown Prince told Mag (his wife) that it was a difficult job to be a king, thereby confirming the Swan of Avon. He said that whatever one supposed a Norwegian would do he invariably did the opposite. Indeed there was nearly a bloodless revolution while we were there; the Prime Minister of Norway was there and I believe the dilemma was only postponed.

Ramsay remained at University College until 1912, when he retired. Two years prior to this, in conjunction with Dr. Gray, he determined the density of the emanation obtained from radium (which Ramsay named "niton") involving the mastery of experimental detail which established him once for all as the great wizard of the laboratory. The total volume of the gas under examination was not much beyond 1/10 cubic millimeter—a bubble which can scarcely be seen. To weigh this amount at all accurately required a balance turning with a load not greater than 1/100,000 milligram. When war broke out Ramsay placed his services at the disposal of the government. Much he could not do. In July, 1915, he writes to a friend that he had had several huge polypi extracted from his left nostril. "I have stood them for years, one gets into the habit of bearing discomforts, but it is a great relief." The relief was to be only temporary. Another operation became necessary in November.

> I was in the surgeon's hands on November 10th and again on the 13th, and he did an operation on my left antrum for a tumor, I believe very successfully. Since then, last Monday, I was irradiated for 24 hrs. with X-rays as a precaution against recurrence. Luckily it is of the kind which can be stopped by Radium. I have had a very bad time.

He died on July 23, 1916. He had lived not a long life but a very fruitful one and a very happy one. Writing to Presi-

[12] The sum of money attached to each prize amounts to about $40,000.

dent Ira Remsen, of Johns Hopkins, a few months before his death Ramsay concludes his letter with:

> Well, I am tired, and must stop. I look back on my long friendship with you[13] as a very happy episode in a very happy life; for my life has been a very happy one.

Ramsay was many-sided. He was an excellent example of the very opposite of Punch's dry-as-dust philosopher. Among musicians[14] and among artists[15] he held his own, for he was an accomplished amateur in both fields. As a linguist he probably has had few equals among scientists. And those of us who, as late as 1912, heard him move a vote of thanks to Professor Gabriel Bertrand, of the Sorbonne, after the latter's lecture to the members of the International Congress of Chemists, will have formed a pretty good picture of his charm and ability as a speaker. Of the many letters that have been preserved, perhaps none sums up so well the characteristics of Ramsay as the following, written to his friend, Dr. Dobbie:

LE HAVRE,
Monday, the Something or other August, 1877.

My dear Dobbie,

Some fool of a Frenchman has stolen all the paper belonging to the French Association, and has left only this half sheet with Le Havre at the top. From the preceding sentence you will have already guessed that the French Ass. is capering around Havre at present, that I form one of the distinguished foreign members, and that all is going as merrily as a marriage bell. Voici 5 jours that I find myself here. I went to Paris with three spirits more wicked than myself, lawyers—a fearful compound 3 lawyers and a chemist—just like NCl_3 for all the world, liable to explode at any moment. . . . I have made the acquaintance with a whole lot of chemists, Dutch and French, and have found an old Dutchman named Gunning ravished to find someone who shares his ideas about *matter*, chemical combination, etc. We excurted yesterday the whole day and talked French and German alternately all the time. When we wanted to be particularly distinct French was all the go. For energy and strong denunciation German came of use. You can't say "Potz-teufel!" in French or "Donnerwetter potztausend sacramento!" An old cove, also a Dutchman, DeVrij, with bowly legs and a visage like this (sketch profile) is also a very nice old boy. The nose is the chief feature of resem-

[13] Dating back to the Tübingen days.

[14] "I spent many evenings at their home, where William (Ramsay) enlivened the company with songs, which in later years were greeted with enthusiastic applause by his students at social evenings of the University College Students' Club. . . . He had a very good voice, played his own accompaniments, and was an expert whistler."—Oho Hehner, a friend.

[15] "Another amusement of Ramsay's was sketching in water colors, an art in which he possessed no inconsiderable share of the talent which belongs to his cousins, Sir Andrew Ramsay's family."—Sir James Dobbie.

blance in the annexed representation. Wurtz and Schukenberger are both Alsations and of course are much more gemüthlich than the echter Französe, but on the whole the fellows I have got to know are very pleasant. Some of the younger lot and I kneipe every evening. Then we bathe every day too in fine stormy water.[16] Eh bien, what is there to say of more? I am going straight back to Glasgow on Wednesday by the special steamer to Glasgow. My money is about done, so I must bolt. . . . By the way I forgot to tell you that I had the cheek to read a communication on picoline, in French, which was received with loud applause. There was some remarks made afterwards very favorable, tho' I say it as shouldn't say it. Adoo. Write to Glasgow and tell me wie geht's.

Yours very Sincerely,

W. Ramsay.

[16] "He (Ramsay) was a very strong and graceful swimmer and could dive further than any amateur I have seen. When we were in Paris in 1876 the four of us used to go to one of the baths in the Seine every forenoon, and after the first time, when Ramsay was ready to dive, the bathman would pass round the word that the Englishman was going to dive, and everyone in the establishment, including the washerwoman outside, would crowd in and take up positions to watch him. He dived the whole length of the bath and sometimes turned there under water and came back a part of the length."—H. B. Fyfe, a life-long friend.

A POSSIBLE NEW SOURCE OF FOOD SUPPLY

By Professor P. W. CLAASSEN
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MUCH attention has been given during the last few years to the question of foods. We have learned to use in our bakings and to like on our table various substitute flours that hitherto were not considered worthy of trial. Many of the flours have proved to be palatable and nourishing.

Among the many products which the Indians have taught us to use may be mentioned such common and now indispensable foods as corn and potatoes. Probably when man first sampled potatoes he did not relish them, but gradually learned to like them. Likewise the white man has learned to use corn and both corn and potatoes are now considered indispensable foods.

There are, however, many products which the Indians used and relished that have received little or no attention from the white man. The common cat-tail (*Typha*) is one of these products. Parker,[1] in speaking of the "Iroquois Uses of Maize and other Food Plants," says:

> The roots of the cat-tail were often used. Dried and pulverized the roots made a sweet flour useful for bread and pudding. Bruised and boiled fresh, syrupy gluten was obtained in which cornmeal pudding was mixed.

Others have spoken of the possibility of the cat-tail plant as a source of food supply. J. D. Hooker, in his "Descriptive and Analytical Botany," page 827, says: "The pollen of *Typha* (cat-tail) is made into bread by the natives of Scind and New Zealand." And again the botanists, Engler and Prantl, state that "the rhizome rich in starch may serve as food material."

The vast areas of cat-tail have been little utilized. Here is a plant with prolific growth, rich in starch and other products of food value, growing in situations now regarded as waste lands.

The cat-tail is a perennial plant with large underground rootstalks or rhizomes. Several of these rhizomes originate from a single plant. They spread in all directions and run underground for distances of twelve to thirty inches or more, then suddenly turn and come out and form other stalks. Thus

[1] Museum Bulletin 144, N. Y. State Museum.

A Typical Cat-tail Marsh.

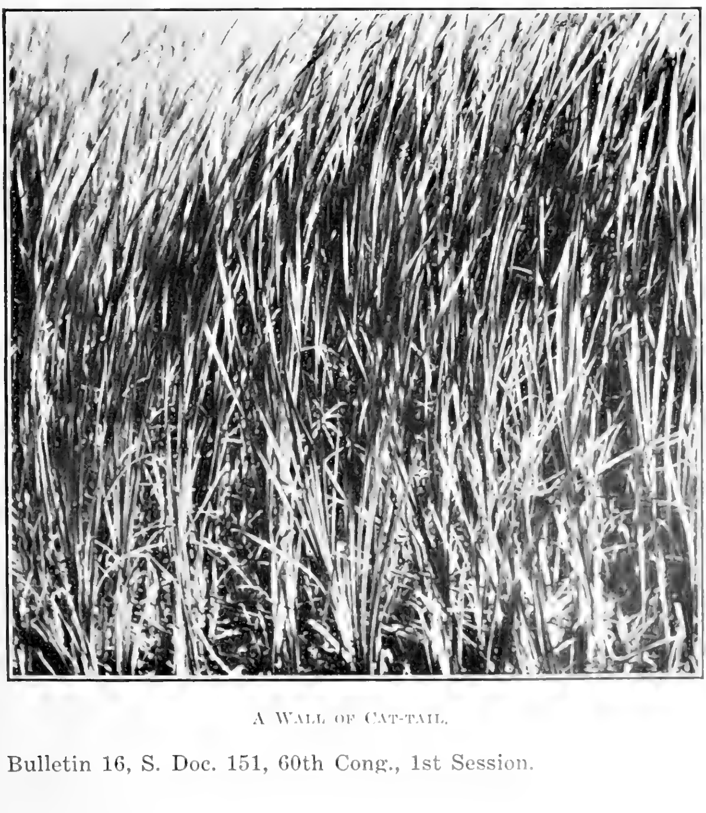
in any cat-tail patch three to four inches under the surface of the ground one finds an irregular network of these rhizomes. To these rhizomes are attached the roots and root-hairs which gather the food material from the soil. The rhizomes, which measure three fourths to one inch in diameter, are the storing places for the reserve food that has been manufactured by the green leaves. The center of the rhizome consists of a core of more solid material, an almost solid mass of starch. This core measures three eighths to one half inch in diameter. Surrounding this core of starch one finds a layer of spongy tissue, such as occurs around the roots of many of the swamp plants. It serves as a protection or as an insulator to the central core of the reserve food material.

During the growing season the cores of the rhizomes become filled with grains of starch. With this bountiful supply of reserve food material on hand, the cat-tail is able to send forth its new leaves the following spring just as soon as the frost is out of the ground. A remarkably rapid growth is thus insured. However, in this process of food manufacturing and storing, the cat-tail is not so different from many other plants. All plants store up food material in some form or another. The potato concentrates its food material in the tuber in the ground preparatory to the following year's crop. The sole purpose of this large starch supply in the potato is to provide enough reserve material for the young plant till it is able to maintain itself. Likewise the cat-tail provides for its "progeny." It is nature's way of insuring the maintenance of its species.

Man has taken advantage of many of the stored products of nature and come to depend upon them largely for his sus-

tenance, but there is still much food going to waste in so far as man's own interests are concerned. The cat-tail produces a surprisingly large amount of food material. The plant grows in situations which are at present little or not at all utilized. According to C. A. Davis,[2] there are in the United States, exclusive of Alaska, 139,855 square miles of swamp land. Thousands of acres of this land are cat-tail marshes. These marshes annually produce thousands of tons of food material. Only indirectly has man learned to reap some benefit from these cat-tails, for annually scores and scores of muskrats are trapped in the marshes. The sustenance of these muskrats consists largely of the rhizomes of the cat-tail.

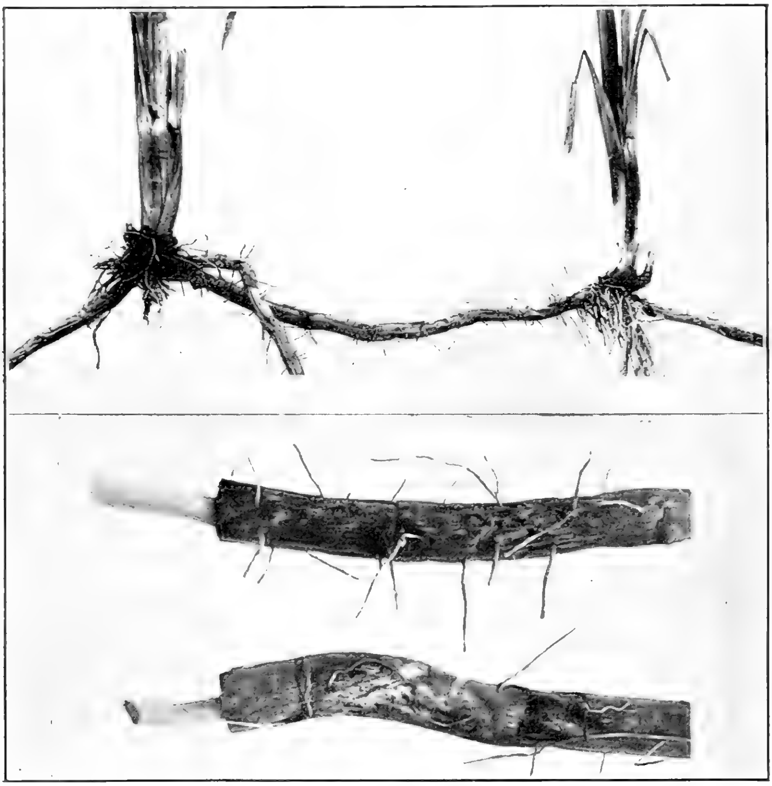
Knowing that the Indians had made use of the cat-tail as a food, and knowing that such animals as muskrats thrive on this food, it was thought worth while to investigate the value of the cat-tail plant as a source of food supply. Should it prove to be of value and should it be possible or practicable to obtain the food and prepare it in some form, it might prove to be another valuable asset in this or in some other country. With an ordinary pickaxe a square yard of cat-tails were dug up in a mod-



A WALL OF CAT-TAIL.

[2] Bulletin 16, S. Doc. 151, 60th Cong., 1st Session.

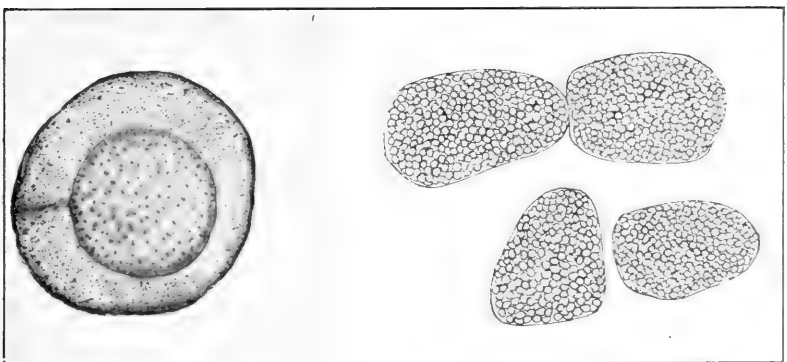
erately thick patch. The tops of the plants were cut off, the rhizomes washed and taken to the laboratory. Here the entire bundle of rhizomes was weighed. Thus the total weight of rhizomes obtainable from a square yard was found. This amounted to 6.7 pounds. Much of this weight, however, was water. The rhizomes were put upon a radiator and left till they were thoroughly dry. This required from five to eight



Two Cat-tail Plants showing the Underground Stems or Rhizomes.
Note the new offsets at the bases of the old plants.
Two pieces of Rhizome with part of the outer Covering removed to show the relative size of the Central Core from which the Flour is derived.

days. The dry weight of the rhizomes was 2.23 pounds, or one third of the original weight. Calculating from these figures we find that one acre of cat-tail would yield a total dry weight of rhizomes of 10,792 pounds. The next part of the problem was to determine what part, by weight, of the rhizome consisted of the central core of starch. Various methods were employed in attempting to separate the central core from the surrounding layer of spongy tissue. It was found that while

the rhizomes were still wet the spongy tissue peeled off quite readily, in fact it could be stripped off very much in the manner that one strips off the bark of a small tree. This left the central core quite clean. If, however, the rhizomes were left till partly dry the outer layer would not separate so easily and much of the core was lost in attempting to separate the two. But if the rhizomes were left till completely dry the outer layer came off very readily and left the clean, hard central core. Careful weighings showed that in the dried rhizome the central core constituted 60 per cent. of the total weight of the rhizome. Taking 60 per cent. of the above 10,792 pounds, we find that one acre would yield 6,475 pounds of material composed of the cores. These cores contain many fibers, and our next attempts were made to separate these fibers from the rest of the material. The cores were ground up and the grindings placed in water, thus attempting to separate the starch from the fibers



CROSS SECTION OF A RHIZOME. Except for the fibers the cores are composed of a solid mass of starch.
A FEW CELLS FROM THE CENTRAL CORE MUCH ENLARGED TO SHOW THE GRAINS OF STARCH.

by gravity. This method, however, did not prove satisfactory since much of the starch went into solution and few of the fibers came to the surface. A syrupy solution also forms which tends to hold the grains of starch and the fibers together. Secondly, the dried cores were ground up finely by passing them several times through an ordinary meat grinder and then sifting through a fine mesh sieve. Much of the fibrous material was thus got rid of. The siftings proved to be a fine flour of a white or slightly creamy-white color and not much different in general appearance from wheat flour. By this crude method of separating the fibrous material from the cores we found that from 10 to 15 per cent. by weight of the cores proved to be fibrous material, leaving a net weight of 5,500 pounds of the

siftings or flour available per acre. Of course, not all of the fibrous material was got rid of by this method, but likewise part of the flour was lost with the fibers, so that the above figures probably represent a fair average estimate.

A sample of the flour thus obtained was sent to Washington to the Food Administration office. This office turned the sample over to the Plant Chemical Laboratory, where an analysis of the flour was made. This analysis shows the following composition:

Moisture	7.35 Per Cent.
Ash	2.84 Per Cent.
Fat	0.65 Per Cent.
Protein	7.75 Per Cent.
Carbohydrates	81.41 Per Cent.

Mr. J. A. LeClerc, the chemist in charge, in his report on the analysis says:

You will see from this that this material has approximately the same amount of protein that is found in rice and corn flours. The ash content is very high, however. In this respect it approximates the amount found in potato flour and in cassava flour and in dasheen flour. The fat content is somewhat lower than that found even in wheat flour. In view of our experience on the use of flour substitutes in baking we see no reason why cat-tail flour could not be used to the extent of 10 to 20 per cent. as part substitute for wheat flour.

Two samples of the flour were also analyzed by the Food Laboratory of the University of Kansas. Sample no. 1 consisted of the flour just as the cores were ground up without attempting to remove the fibers. Sample no. 2 had the fibers removed similarly to the sample that was sent to Washington. These two samples show the following composition:

	No. 1, Per Cent.	No. 2, Per Cent.
Moisture	6.77	8.78
Ash	2.37	2.48
Protein	5.71	7.22
Fat (ether extract)	3.71	4.91
Carbohydrates (different)	83.81	79.09

It may be of interest to show in tabular form the analyses of several flours in order to compare them to the cat-tail flour. The figures in these tables for the flours other than cat-tail have been taken from Bulletin 701, U. S. Department of Agriculture, Washington, D. C.

Chemical Analysis of Wheat-flour Substitutes and of Cat-tail Flour.

Kind of Flour	Water, Per Cent.	Ash, Per Cent.	Fat, Per Cent.	Protein, Per Cent.	Carbohydrates, Per Cent.
Spring wheat	12.00	.42	1.00	12.50	73.83
Yellow corn (raw)	6.96	.82	2.82	7.88	80.83
Rice (polished)	9.65	.36	.24	8.81	80.74
Potato (dried)	6.82	4.01	.43	12.25	74.80
Cassava	8.21	1.60	.29	1.44	86.45
Dasheen (peeled)	7.48	4.12	.46	8.00	77.80
Cat-tail (Washington analysis)	7.35	2.84	.65	7.75	81.41
Cat-tail no. 1, Univ. of Kans. anal.	6.77	2.37	3.71	5.71	83.81
Cat-tail no. 2, Univ. of Kans. anal.	8.78	2.48	4.91	7.22	79.09

A comparison of the above analyses shows that the cat-tail flour is not so different in composition from other flours and could probably well be used.

The practicability of obtaining the flour from the field is a question which deserves further attention and experimentation. Likewise the question of cultivation would require careful investigation. The fact, however, remains that there are thousands of acres of cat-tails containing considerably over two tons of flour per acre which at present finds no use.

We have found that it is not so difficult to get the flour in small quantities. Half an hour at digging and "peeling" has yielded three or four cupfuls of flour. The digging is not so different from digging potatoes and the peeling about equally facile.

We have used this flour in several ways, first as part substitute flour in baking, and secondly as a substitute for cornstarch in puddings. Biscuits made with 33 per cent. and 50 per cent. cat-tail flour were found to be very palatable. Even 100 per cent. cat-tail flour made biscuits that were not so different from biscuits made from wheat flour. Puddings made with cat-tail flour in them in place of corn starch proved to be entirely satisfactory. The flavor produced by this flour is pleasing and palatable.

Dr. Abraham Jacobi

THE PROGRESS OF SCIENCE

DR. ABRAHAM JACOBI

In the death of Dr. Abraham Jacobi the medical profession and New York City lose "the good physician" and a fine personality linking them with the middle of the last century. He had practised medicine in New York for sixty-five years and had witnessed and assisted in causing the great changes that have taken place during that period, both in his profession and in the city. Dr. Jacobi occupied the first chair for the diseases of children in the United States, having been appointed professor at the New York Medical College in 1860, and maintained to the end of his long life leadership in all matters concerned with the medical treatment and hygienic care of children.

Abraham Jacobi was born eighty-nine years ago in a Westphalian village, of Jewish parents, his father having been a peddler and keeper of a small shop. By his own efforts and ability he made his way through school and university, taking part as a medical student in the revolutionary activities of 1848. After two years of imprisonment, he came to the United States. Under the circumstances a subsequent call to a chair in the University of Berlin was a notable tribute.

When Dr. Jacobi first came to New York, he opened an office in which the fee was twenty-five cents, but his medical training, such as at that time could not be obtained in this country, and his remarkable personality soon gave him prominence in the profession. Dr. Stephen Smith, one of the editors of the *New York Journal of Medicine*, who celebrated his ninety-sixth birthday recently, invited him to write for the journal, and from that time forward he became a constant contributor to medical literature. His first book was a treatise on the diseases of women and children, prepared in cooperation with Dr. Emil Noeggeratt, and published in 1859. This was followed by other volumes and monographs, mainly concerned with the diseases of children, but also treating cancer, diphtheria and intestinal diseases.

After the closure of the New York Medical College, Dr. Jacobi became a member of the faculty of the New York Medical College, and in 1870 became clinical professor of the diseases of children in the College of Physicians and Surgeons of Columbia University, which chair he occupied until his retirement as professor emeritus in 1902. Dr. Jacobi had been connected as visiting physician with a number of public hospitals in New York City, the fiftieth anniversary of his continuous service at the Mount Sinai Hospital having been celebrated in 1910.

Dr. Jacobi was always active in medical organization, having been president of the American Medical Association, the Association of American Physicians, the New York Academy of Medicine and other societies. He took part throughout his life in all movements for the welfare of the community, more especially in those concerned with the housing, food and care of infants and children.

On the occasion of Dr. Jacobi's seventieth birthday a *Festschrift* containing scientific contributions by fifty-three colleagues was presented to him at a largely attended dinner. On his eightieth birthday the Medical Society of the State of New

Unveiling of the Statue of Ezra Cornell

York held a reception in his honor, and presented to him a bronze medallion portrait. Preliminary arrangements had already been made for the celebration of his ninetieth birthday, which would have occurred on May 6 of next year.

In 1873, Dr. Jacobi married Dr. Mary C. Putnam, a physician of distinction, active in promoting the medical education of women, who died in 1906.

At the dinner in honor of Dr. Jacobi's seventieth birthday, referred to above, the following verses by the late Dr. S. Weir Mitchell were read:

That kindly face, that gravely tender look,
Through darkened hours how many a mother knew!
And in that look won sweet reprieve of hope,
Sure that all Earth could give was there with you.

THE SEMI-CENTENNIAL OF CORNELL UNIVERSITY

Cornell University was chartered in 1865 and opened in 1868. The celebration of its completion of fifty years was postponed on account of war conditions and took place at the recent commencement with some four thousand alumni in attendance. The principal exercises were held out of doors when addresses by President Schurman, Governor Smith, Judge Hiscock, and Justice Hughes were delivered in the Schoellkopf Stadium. The speakers spoke from a platform, built large enough to hold a glee club, and fitted with an effective sound amplifier that carried the voices perfectly.

Another occasion of interest was the unveiling of the statue of Ezra Cornell by his daughter, after which President Schurman and Professor Crane paid tribute to the character and work of the founder of the university. The statue has been placed between Morrill and McGraw Hall. The illustration here reproduced gives a glimpse of the beautiful outlook from the Cornell Campus.

Each college and several departments held conferences of alumni and faculty to discuss educational problems. The opinion seemed general among those who attended that the conferences were distinctly successful, and that, contrary perhaps to the prevalent opinion when the plan was first announced, the alumni were sympathetic, encouraging, and alert to the educational work of the university. A special reunion brought back some sixty physicists to do honor to Edward L. Nichols, '75, the retiring head of the department of physics, who during the thirty-two years of his professorship has done great service for education at Cornell and research throughout the country.

It is said that a record was established by serving a course dinner to four thousand alumni in the Drill Hall, and a supper of the same magnitude was served the following evening. Miss Mary Louise Thatcher, a graduate of the Home Economics Department, who is not yet twenty-six years of age, was responsible for the arrangements, and five hundred men and women students volunteered to do the tasks of waiting on the tables.

There were many fraternity and class reunions and the usual athletic events, including a display of airplanes. One event usual at such celebrations was lacking, for Cornell has the distinction of not conferring honorary degrees.

Cornell University, somewhat removed from the Atlantic seaboard, occupies also educationally a position intermediate between the eastern private corporations and the state universities. The governor and other state officers are trustees, and the State College of Agriculture is conducted in cooperation with the university. Women are admitted on equal terms, and attention has been

paid to practical studies. Perhaps it meets as nearly as any university the conditions of Ezra Cornell's oft-quoted words: "I would found an institution where any person can find instruction in any study."

THE AMERICAN FEDERATION OF LABOR ON SCIENTIFIC RESEARCH

At the recent Atlantic City Convention of the American Federation of Labor a resolution was passed as follows:

Whereas, scientific research and the technical application of results of research form a fundamental basis upon which the development of our industries, manufacturing, agriculture, mining, and others must rest; and

Whereas, the productivity of industry is greatly increased by the technical application of the results of scientific research in physics, chemistry, biology and geology, in engineering and agriculture, and in the related sciences; and the health and well-being not only of the workers but of the whole population as well, are dependent upon advances in medicine and sanitation; so that the value of scientific advancement to the welfare of the nation is many times greater than the cost of the necessary research; and

Whereas, the increased productivity of industry resulting from scientific research is a most potent factor in the ever-increasing struggle of the workers to raise their standards of living, and the importance of this factor must steadily increase since there is a limit beyond which the average standard of living of the whole population can not progress by the usual methods of readjustment, which limit can only be raised by research and the utilization of the results of research in industry; and

Whereas, there are numerous important and pressing problems of administration and regulation now faced by federal, state and local governments, the wise solution of which depends upon scientific and technical research; and

Whereas, the war has brought home to all the nations engaged in it the overwhelming importance of science and technology to national welfare; whether in war or in peace, and not only is private initiative attempting to organize far-reaching research in these fields on a national scale, but in several countries governmental participation and support of such undertakings are already active; therefore be it

Resolved, by the Amedican Federation of Labor in convention assembled, that a broad program of scientific and technical research is of major importance to the national welfare and should be fostered in every way by the federal government, and that the activities of the government itself in such research should be adequately and generously supported in order that the work may be greatly strengthened and extended; and the Secretary of the Federation is instructed to transmit copies of this resolution to the President of the United States, to the president pro tempore of the Senate, and to the speaker of the House of Rrepresentatives.

THE PROPOSED MEDICAL FOUNDATION FOR NEW YORK CITY

Announcement has been made by Dr. Royal S. Copeland, health commissioner of New York City, of an organization to be known as the New York Association for the advancement of Medical Education and Medical Science.

The association's constitution and by-laws have already been adopted and an application has been filed at the Secretary of State's office in Albany for a charter. Dr. Wendell C.

Phillips, ear specialist and general surgeon for Bellevue Hospital, is the president, and Dr. Haven Emerson, formerly health commissioner of New York, is the secretary.

Dr. Phillips, who is the originator of the project, planned before the war for an institution that would at least rival Vienna and Berlin. The world conflict postponed the matter, but as soon as the armistice was signed the physician and those interested with him revived the plan. A meeting was held on April 10, at which prominent medical men gave their views, and a committee was appointed to deal with the matter.

As stated in the constitution of the association, there are four primary objects to be attained. There are: First: To improve and amplify the methods of graduate and undergraduate teaching. Second: To perfect plans for utilizing the vast clinical material of the city for teaching purposes and to make use of teaching talent now unemployed. Third: To bring about a working affiliation of the medical schools, hospitals and laboratories, as well as the public health facilities of the city, to the end that the best interests of medical education may be conserved. Fourth: To initiate the establishment of a medical foundation in New York City whereby funds may be secured to meet the financial requirements of all forms of medical education and investigation.

There will be two classes of membership in the organization, one a general membership, including all physicians in good standing, teachers of auxiliary sciences, and investigators of problems relating to medicine; the other, a corporate membership of medical teachers and medical men with hospital appointments or affiliations. The corporate membership is limited by the constitution to not over 150.

The physicians who are responsible for the plan issued a short statement, which was given out at the board of health offices, in which they said:

For years it has been evident that medical education, both undergraduate and graduate in New York has not adequately represented the possibilities of this great city. One of the reasons for this state of affairs has been the lack of financial support for our medical institutions. A more potent reason, however, arises from the fact that individual institutions working along somewhat narrow lines have accomplished satisfactory general results. The larger possibilities which could only come from a more or less central organization have failed to materialize.

As a result, men seeking medical education have been obliged to seek medical centers in European countries where more individual and special courses could be secured with but little trouble.

It is a historical fact that after every great war, the medical center of the world is changed and the war just over will be no exception to the rule. In line with these ideas and in order to give New York City this opportunity to at least become one of the leading teaching medical centers of the world, our organization has been formed.

In addition to Dr. Phillips and Dr. Emerson, the following compose the officers of the association: Dr. George D. Stewart, president of the New York Academy of Medicine, first vice-president; Dr. Glentworth Butler, chief medical consultant of the Long Island College Hospital, second vice-president; Dr. Arthur F. Chace, stomach specialist of the Post-Graduate hospital, treasurer. The trustees are Colonel Charles H. Peck, Dr. William Francis Campbell, Dr. John E. Hartwell, Dr. Frederick Tilney, Dr. Otto V. Huffman, Dr. Adrian Lambert, Dr. Samuel A. Brown, Dr. James Alexander Miller, and Dr. George W. Kosmak.

SCIENTIFIC ITEMS

We record with regret the death of Lord Rayleigh, the great English

physicist, and of Emil Fischer, the distinguished chemist of the University of Berlin.

Dr. George E. Hale, director of the Mount Wilson Observatory and foreign secretary of the National Academy of Sciences, who has been for the last ten years a correspondent of the Paris Academy of Sciences, has been elected a foreign associate, taking the place of Adolph von Baeyer, declared vacant by the academy. The foreign associates are limited to twelve, and the distinction has been held by only two Americans—Simon Newcomb and Alexander Agassiz.

Professor Albert A. Michelson, head of the department of physics at the University of Chicago, has been appointed to the rank of commander, U.S.N.R.F. He served as lieutenant commander in the Bureau of Ordnance of the Navy Department at Washington during the war.

Colonel J. G. Adami, F.R.S., professor of pathology, McGill University, Montreal, has been elected vice-chancellor of the University of Liverpool, in succession to Sir Albert Dale.

The eighty-seventh annual meeting of the British Association will be held in Bournemouth from September 9 to 13, under the presidency of the Honorable Sir Charles Parsons, who will deliver an address dealing with engineering and the war. The following presidents of sections have been appointed by the council: A, Mathematical and Physical Science, Professor Andrew Gray; B, Chemistry, Professor P. Phillips Bedson; C, Geology, Dr. J. W. Evans; D, Zoology, Dr. F. A. Dixey; E, Geography, Professor L. W. Lyde; F, Economic Science and Statistics, Sir Hugh Bell, Bart.; G, Engineering, Professor J. E. Petavel; H, Anthropology, Professor Arthur Keith; I, Physiology, Professor D. Noel Paton; K, Botany, Sir Daniel Morris; L, Educational Science, Sir Napier Shaw, and M, Agriculture, Professor W. Somerville. Evening discourses will be delivered by Sir Arthur Evans on "The palace of Minos and the prehistoric civilization of Crete"; and by Mr. Sidney G. Brown on "The gyroscopic compass."

An alumni memorial to honor Dr. C. R. Van Hise, late president of the University of Wisconsin, has been proposed in the form of a Van Hise Memorial Geological Building to be erected on the campus to bring together under one roof the departments of geology and mining engineering, as well as the state and national geological surveys.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1919

THE BEGINNINGS OF HUMAN HISTORY READ FROM THE GEOLOGICAL RECORD: THE EMERGENCE OF MAN[1]

By Professor JOHN C. MERRIAM

UNIVERSITY OF CALIFORNIA

AS now interpreted history means nothing if it does not present connected series in which every part contributes somewhat to the interpretation of all other parts or is in turn interpreted by them. Features of contrast may serve as markers for stages of movement and degrees of change, but the essential interest of the subject is embodied in the idea of continuity or unity.

The concept of evolution as we use it in science is only another form of expression for continuity in historic series presenting sequences of apparently different elements. It represents the idea of growth. It involves rate of development and nature of the forces controlling it. It interprets present conditions in terms of the past, and furnishes to some extent a basis of calculation for prediction of the future.

In the preceding lectures of this series your attention has been directed out over the stellar world, and back in time through certain evident transitions by which its existing stages have been reached. The earth which we inhabit has been shown to you shaping into its present form, and the living world upon it has been passed in review through numberless evolutionary changes leading up to its present highly differentiated, and relatively complicated phases. The mechanism of evolution has also been set forth as we now see it. Astronomer, geologist, paleontologist and biologist have all expressed the idea of growth.

[1] Delivered before the National Academy of Sciences in April, 1918, as the sixth series of lectures on the William Ellery Hale Foundation.

While the passage from stellar to geologic evolution has consisted mainly in narrowing of view to special processes, the introduction of an organic or life sequence has involved a most difficult transition, seeming superficially of a qualitative type, and presenting one of the great problems barring our way to a full interpretation of nature.

Considering the evident physico-chemical and biological characters of man, resembling those represented in the general scheme of animal evolution, and taking these characteristics together with man's relatively advanced stage of intelligence and constructive ability, it has been natural to think of the human organism as the next member of a graded series beyond the stage seen in biological or paleontological history. This might of course be done without assuming relationship between man and nature. It is, however, logical to inquire whether there is not actually full continuity between the biological world and the distinctly human sphere. As humans, no problem of greater fundamental significance faces us in contemplation of the historical or origin sequence in nature.

At a time when our world has just emerged from a conflict involving the making of history of unexampled significance, it may seem that consideration of the beginnings of our story might well wait upon better opportunity for such luxury as speculation regarding an unchangeable past. This view we might well hold were it not clear that future world adjustments, brought immediately before us by the present crises, involve many heretofore little-heeded factors, among which are included those biological aspects of human life and social organization striking their roots down to the lowest strata of history.

Every nation with a clear vision now realizes that with the widely differing peoples of the earth brought in immediate contact by modern rapid transportation, by lightning communication, and by the reaching out of interdependent industries, international difficulties can be settled or prevented only through understanding of the nature, environment and needs of every nation and race. This comprehensive view of the world situation will not be alone the interpretation of the diplomat, of the international lawyer, or of the business man concerned primarily with trade for profit. It will necessarily include perception of the essential similarities and differences of race, understanding of racial and national psychology, of special abilities of peoples for accomplishment in particular directions, and of peculiar needs of races and nations. Together with these

factors, which have their basis largely in heredity, we must know the true influence of environment, of culture and of language.

The knowledge which we require is such as can be reached only by the fullest attainable understanding of the true nature of every phase of the human type in every aspect of its being. As a part of the required information, it will be essential that we have clearly outlined the background of our entire history, setting before us the evidence as to what we are, by showing us how we came to be.

Approaches to Early Human History

Approaches to early human history have been made by many roads; one has been that of the investigator working his way back from present to earlier time by way of documentary history, and finding a lower limit in the beginning stage of written record set down by use of hieroglyphs or alphabets. We have also the approach through work of the philologist and the ethnologist suggesting relationships and origins through similarities of language and custom. Advance to still earlier stages of the human record are made by way of archeology, basing its method in part upon physical superposition of strata in determination of culture sequence. Carrying us still farther down is that aspect of paleontology connected on the one hand with the study of cultures through archeology, and on the other hand basing history upon succession of faunas and floras, and using the sequence of strata worked out by the carefully elaborated technique of the geologist. To these views there must then be added the speculations of the biologist upon relationships of the human family, which naturally follow a broad application of the evolution theory.

There can be no field of science which does not, in addition to its peculiar individuality, represent also the meeting place of other sciences, as, for example, chemistry is indissolubly connected with physics and is expressed in terms of mathematics. There are, however, few cases in which the information required for construction of the complete story has remained for a longer period so widely scattered and so sharply divided into the various elements needed for understanding of the subject, as have the materials used in constructing the beginnings of human history. As in the development of the relationships of many other sciences, starting from widely separated points, the student of documentary history, the philologist, the archeologist, biologist, geologist and paleontologist have all worked

out from their special regions until the widening boundaries overlapping have given us the present field of early human history.

Consideration of that phase of the problem concerning the emergence of man or the beginning of human history is essentially then an archeological and paleontological problem read out of the geological record. The evidence as we know it unquestionably carries us back into records representing geological periods long antedating the present age in the earth's story. Although no sharp distinction exists between the methods of the archeologist and those of the geologist, it seems clear that the interpretations of the geologist and paleontologist with the cooperation of the biologist must be the dominant elements in obtaining our understanding of the earliest stages of human life.

It is the purpose of the two lectures given at this time to deal with that portion of the historical series covered by the *emergence* of man and the stages of his history before the dawn of civilization. While the question is essentially comprised within the realm of geologic and paleontologic research, it is necessary to consider also such evidence as may be secured from other sources indicating the place of the human type in the natural world, with whatever data may be found to furnish suggestions concerning the origin and ancestry of man. The inquiry concerns specifically a particular portion of actual history, for which the explanation or cause must be furnished by evidence secured on other lines of thought.

Biological Position of the Human Type

A study of the beginnings of human history, considered from the point of view of an investigator passing in review the evolutionary process, involves the biological relationship of man to other groups or organisms. Before presenting the evidence of human history from the paleontologic and geologic side it is desirable to set up as a background such information as we have from other sources concerning the possible biological relationships of the human family. These considerations are taken up with a view to determining their value in interpretation of man's place in nature, and the possibility of his growth or evolution out of the natural world. They comprise:

1. The question of existing human differentiation. Do laws of variation, such as are found in other groups of organisms, obtain also among humans? In other words, is a biological scheme of classification naturally expressed within the human group?

2. The problem of geographical distribution of human variations with special relation to the question of origin and classification of such differing types.

3. The problems of comparative anatomy and physiology, including consideration of the question whether man's body is structurally similar to that in the higher animals.

Physical Variation in the Human Group, and Classification of Subgroups

Bringing into review the whole range of variation of the human family in all of its aspects, the differences in structure and in other characters, as color, seem to many biologists comparable to the grades of distinction separating species of horses, wolves, bears, monkeys, and other mammals. There is, to be sure, the unending discussion whether the various *kinds* are to be distinguished as varieties, species or genera; but the settlement of this question is of the same nature as the determination whether the species of one author writing on modern mammals are always comparable with those of another. There may, however, be no difference of opinion regarding existence of these distinctions, or that they represent the natural expression of variation or evolution in these groups of organism.

No biologist coming down from Mars would hesitate to divide the human family into groups comparable to those of other mammals. Though there might be a difference of opinion among the Martians on the question whether certain divisions of the human type should be designated as varieties, species, genera or families, it is probable that the Martians would construct similar classification schemes, their divergence of opinion concerning mainly the question as to nomenclature of the divisions in their similar plans. So the biologists and anthropologists of our own world to-day, without regard to minor differences of opinion, classify the human group. Each division with its peculiarities and its assumed relationships, and each perhaps possessing among its peculiarities possibilities for advance of the world interest not open in the same measure to any other group.

Geographical Distribution

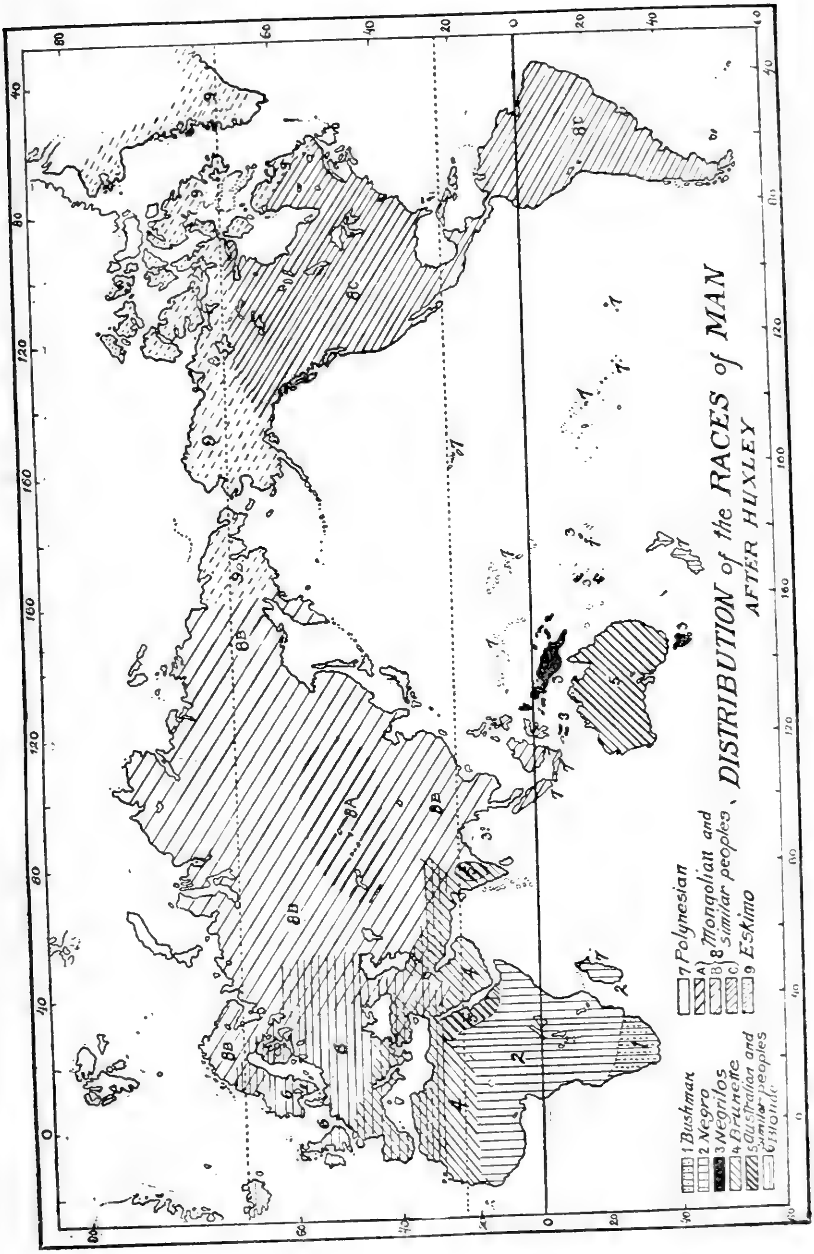
Along with other natural relations, the geographical distribution of man presents a most interesting resemblance to the situation obtaining generally among the higher vertebrates. We frequently find that a map showing distribution of the members of a group of mammals or birds represents in fairly clear

outlines a classification of the subdivisions such as would be made on the basis of morphology. The forms exhibiting the closest resemblances are geographically nearest, but not in the same place, and those that are most widely separated in characters are generally far apart geographically. The whole scheme of distribution when checked against geological history generally shows the group gradually radiating from its place of origin and differentiating more widely as the distribution extends. As shown by W. D. Matthew it is not necessarily true that the peripheral types are the most specialized, they may be primitive forms pushed out from the point of origin, but in general wide geographic separation seems to mean wide morphologic difference. In the case of man we find this geographic grouping of similar types, the geographic separation of more widely differing groups, and the pattern of distribution corresponding in general to the grouping of varieties or species of the human type according to morphological characters.

In the distribution of human types a most striking suggestion bearing upon the relation of distribution to variation is presented in the physical variation among the inhabitants of North and South America. Although there are between one hundred and two hundred linguistic groups in this area, the physical types throughout both continents are not widely different and are very close to those of Asia, the nearest land. A student of modern mammals, equipped with experience in tracing out the history of distribution of groups, would not hesitate in the case of non-human mammals to state that factors of distribution and variation such as we see in the case of man in America indicate that the organisms concerned have been on this continent such a short time that there has been little opportunity for physical differentiation to take place; and that the American forms are evidently derived from an Asiatic source. It may be desirable to mention in anticipation, that the evidence of geological history indicates that man now highly differentiated in the Old World has been present there for a long period, whereas in America, with relatively little differentiated human types, the question as to antiquity extending back as far as the geological period preceding the present is still under vigorous discussion.

Structural Resemblance of Man to the Higher Animals

The physical characters of man generally resemble those of the apes so clearly that discussion of this relationship inevitably resolves itself into a search not for similarities but for differences.



A consideration of features in the anatomy of man assumed to be indicators of relationship requires that reference be made to peculiarities in the development of certain parts of the skeleton which have been held to represent characters of mammals or of reptiles, and to be present in man because of

his descent from these lower types. It has been assumed that, among others, such characters are seen in the presence of separate bones representing ribs attached to the neck vertebræ, and present between the pelvis and the vertebral column of man. These elements correspond to normal functioning bones of the reptile skeleton. They originate and develop to a certain stage in man as in the reptiles, but later fuse with adjoining bones.

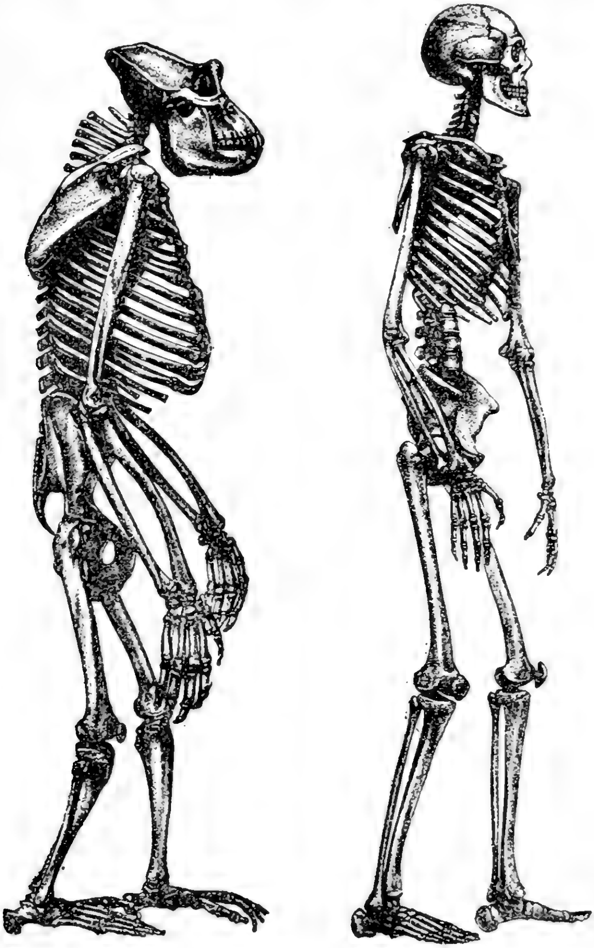
It is possible that some of these structural features have no relation to the question of ancestry of the human skeleton. On the other hand, as in the case of the ribs lying between the vertebral column and the pelvis, and in the growth of the first two vertebræ, there is every reason to believe that the mode of development corresponding to that of the reptiles in these portions of the body is not related to specific needs of the skeleton of man considered either as completed or in process of growth; but that it represents rather a mode of development initiated in a pre-mammalian stage, and persisting in man by reason of the fact that even at this stage in evolution it offers no distinctly unfavorable features. It should also be noted that the mode of development of these elements seen in man is common throughout the mammals, and is most strongly expressed in those forms which most closely approximate the characters of the reptiles.

The anatomical characters distinguishing us from the anthropoids are generally considered to be most sharply expressed in form and dimensions of the brain and skull, and in form and function of the posterior extremities. It is probably unnecessary to proceed farther than to mention the difference between the brain capacity of less than 600 c.c. in a gorilla bulking larger than a man, and an average of about 1,500 c.c. in a Caucasian male, or a minimum of about 950 c.c. for a female Veddah, one of the lower races. Difference in brain capacity is accompanied by skull distinction of which the most readily recognized character is seen in the relatively large size and prominence of the jaws in the apes.

In some respects the difference between man and the apes seems as clearly expressed in the limbs as in the brain, especially since the difference is not merely one of degree, but is in the limbs a distinction of kind and of function. In most apes the relatively long fore-limbs are the principal structures for locomotion, which is by swinging through the trees, and to some extent the hands of these limbs serve the head, though the thumb is not generally opposable. The hind limbs of the apes

are used for grasping and the feet with opposable first toe serve as hands.

In man the relatively long posterior extremities are used solely for walking. The anterior extremities with opposable thumb of the hand serve the head, and as one among many



COMPARISON OF THE SKELETONS OF MAN AND THE GORILLA, presenting especially marked differences in skull and proportions of anterior and posterior limbs. Skeleton of gorilla to left; skeleton of man to right. (Adapted.)

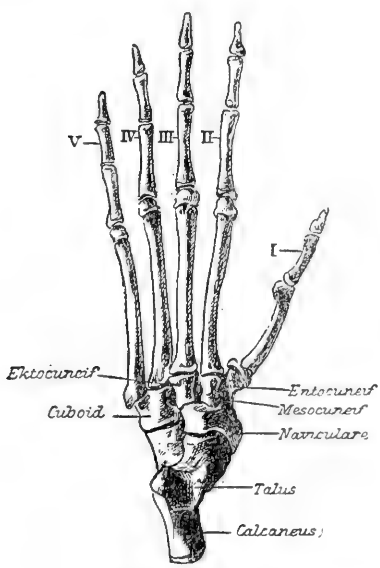
other functions they may be used for climbing. The opposable thumb is specialized to a high degree and freedom from use in locomotion permits the hands a great development of skill in many directions. In apes there are really four hands, but the pair with opposable first digit is situated on the portion of the body farthest from the head, so that neither pair is advantaged to specialize after the manner of the hand of man.

The distal or foot portion of the posterior extremity of both ape and man represents in its fundamental plan the typical extremity of all vertebrates above the fish. It has the same elements arranged in the same order with relation to each

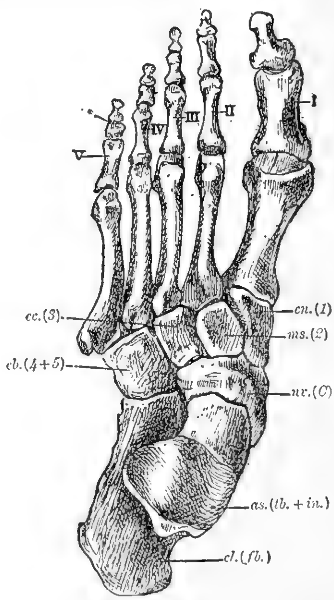
GIBBON. Illustrating extraordinary difference between posterior and anterior limbs. (Adapted.)

other. It is characterized as in normal mammals and reptiles by five digits or fingers in which the inner or first digit corresponds to the thumb and is composed of a smaller number of phalanges or finger bones than the other digits.

In the apes the first digit is, as in normal mammals and reptiles, much shorter than the other, but is distinguished by ex-



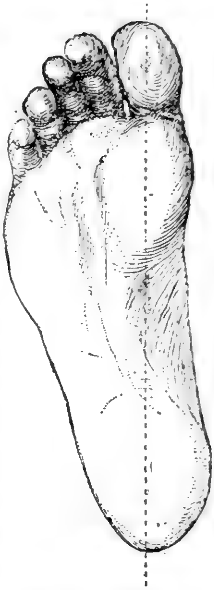
LEFT FOOT OF CHIMPANZEE.
(Adapted from Wiedersheim.)



LEFT FOOT OF MAN.
(Adapted from Wiedersheim.)

traordinary mobility including opposability to the other digits as seen in the thumb of the human hand.

In the foot of man, with the same fundamental plan seen in the apes, we find an extreme modification rarely duplicated in vertebrates, in that the normally short first digit, while retaining the normal number of phalanges for mammals, has been greatly enlarged and elongated until it equals or exceeds the longest of the other digits. It has, moreover, relatively very slight mobility and is not in any sense opposable. The type of modification is so extraordinary among the great number of foot forms known that we must assume for it an important relation to an extraordinary use. This we find indicated in the unusual position of the fore and aft axis of the foot, running obliquely across the foot and through the great toe, instead of through the middle toe as in most forms, giving us a foot with the toes turned out, the weight of the body being borne very largely upon the end of the inner toe. This extreme modification of the human foot is clearly to be coupled with the specialization of the whole limb for running in a long-legged, two-footed form, standing normally with everted toes.



SOLE OF HUMAN FOOT.
(Adapted from Munson.)

According to the paleontologist who relates variation in form to variation in use, these peculiar characters of human feet have come to exist through peculiar use, persistently continued for a long period. It seems that we must set the human type off as very unusually modified for the special function of bipedal locomotion so necessary if the hands are to be set free to serve the head.

Although in the view of many of the earlier writers the human foot differs but little from that of the apes, a number of investigators have inclined toward the view that the differences seen here constitute one of the strongest evidences indicating a considerable gap between man and anthropoids. The separation has seemed sufficiently wide to indicate that the initiation of changes leading toward the human type of extremity must have occurred at a very remote time, at least as early as the incipient specialization of the ape group, tending to produce its peculiar type of adaptation for aboreal life through use of the anterior limbs for swinging or climbing with the hind limbs used for grasping.

In his recent careful review of the subject, Dr. W. K. Gregory takes another view, namely, that the human group may be derived from an anthropoid type which had gone far in the direction of arboreal specialization, and later left the trees and passed through relatively rapid evolutionary stages, producing a long-legged running type with greatly developed big toe. According to Gregory the erect position of man has been made possible by great elongation of arm, permitting fairly erect position of the body in an anthropoid ancestor who rested his weight in some part upon the fore limbs in walking, as in the modern gorilla.

To most students of the problem of structural similarities and differences distinguishing apes and men, the greatest divergences noted are to be classed as differences in degree rather than in kind. This seems in large measure true of skull and brain. The difference in foot structure possibly presents the widest separation and indicates distinction in habits of life conditioned upon locomotion. Should the views expressed by Gregory prove correct, man might conceivably be derived with changes of relatively little significance from forms not unlike the most man-like of modern apes. If other views offer the correct interpretations of structure and of possibilities of modification, the gap is wider and the modern apes will be assumed to represent a type built especially for the trees, while man will be considered as a type long practised in running, long accustomed with free hand to serve a brain given wider opportunity for range of thought. Yet even with this widest gap that we can open the apes are still so near us that with man recognized as a biological type he must, when classified, take his place in the line next to the chimpanzee and the orang.

Conclusions as to Position of Man in Nature

The conclusion which we obtain from a consideration of the biological aspects of the human problem is that physical man may not be separated from the zoological scheme. The sum of evidence from human physical structures gives us an organism dependent upon typical biological processes for its origin, and constructed on the typical mammalian plan. On the basis of general similarity we are obliged to refer the type to that portion of the mammalian group including the monkeys and apes. Such evidence as we secure from comparative anatomy, interpreted through the study of classification and distribution, suggests that the type of man is built up from a form which was originally reptilian, and has passed through many mam-

malian stages before reaching its present level of development. We find the human race showing grouped variations of individuals apparently separated from other variations much as are a large percentage of the generally recognized species of many groups of mammals. We find also that the varying individuals are geographically grouped in a manner paralleling the distribution of mammalian types recognized as species and genera.

From the fact that man is differentiated into clearly separated groups related geographically as are the species of mammals, one might assume that he has been subject to the laws of evolution obtaining in other groups of organisms, and that through a long course of history he has gradually spread himself over the earth, undergoing a process of differentiation concurrent with the extension of his geographic range. In this brief statement, it is not necessary to go farther into consideration of the physiological organization of man than to state that, excepting in minor details, the functioning of this organism is similar to that of the higher mammals of the primate division. The details of physical difference between man and the primates are less than the difference between primates and other groups of mammals assumed to be derived from more ancient forms also ancestral to the primates.

Geological History of the Anthropoids to Which Man Shows Closest Resemblance

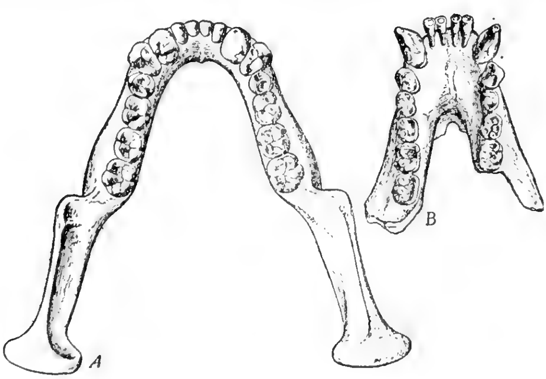
A most interesting chapter in paleontologic evolution, which is necessarily a preliminary to discussion of early human history, is that covering the successive stages of development of the anthropoids to which man shows closest resemblance. If man is considered to be derived from apes, it is necessary to know whether the assumed ancestor existed before man appeared. It is also in many respects as essential to trace the evolution of these hypothetical ancestors up to the branching off of man, as it is to trace man back toward the type from which he is presumed to be developed. Out of the record of anthropoid history it is to be expected that we shall ultimately obtain most important evidence bearing upon the question of man's relationship to the other mammals.

Unfortunately, the available remains of fossil apes are exceedingly fragmentary and include only a limited representation of skeletal parts. Important specimens have been secured from a few localities in Europe, from northern Africa, and, most significant of all, from the great series of Siwalik forma-

tions of southern Asia, representing a large portion of the later geological record. The occurrences of this group in the Siwalik beds of northern India are of unusual importance, as the formations are of considerable geographic extent, of extraordinary thickness, of long geologic range, the relations of the strata are fairly clear, and there is a splendid representation of a long sequence of mammalian faunas associated with the anthropoids. Study of the Siwalik deposits has been followed through the work of the Geological Survey of India for many years, and most interesting results have been secured, especially by Lydekker and Pilgrim. No remains of anthropoids are certainly known from the western hemisphere.

The primate or man-monkey group was in existence, clearly defined, considerably differentiated, and widely distributed in Eocene time, five periods before the present day, or at the beginning of the stage of dominance of the great mammal group. The anthropoid or ape division of the primates was distinctly represented in Africa in the second or Oligocene period of the mammal age. By the middle of the third or Miocene period, forms having in general the characteristics of the orang and the gorilla are found in Asia, and a representative of the gibbons was present in Europe.

Although the known fossil remains of anthropoids are fragmentary, the available material is sufficient to show distinctly a considerable range of forms in which there are present characters approaching those of the human type, as well as the diagnostic features of the gorilla and chimpanzee. Pilgrim basing his views upon recent studies of the Siwalik collections of India

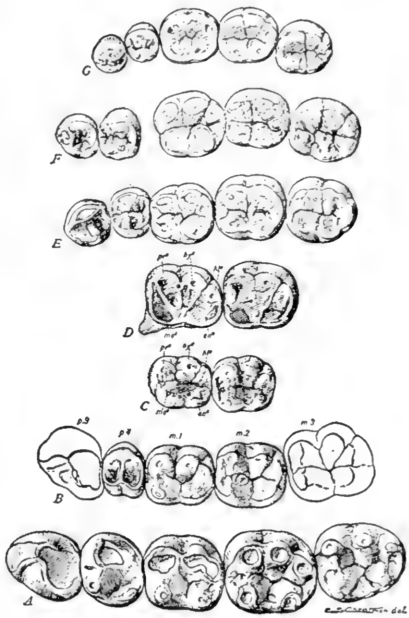


COMPARISON OF *Sivapithecus* AND *Dryopithecus*. Lower jaws, upper view, multiplied by one third. *A, Sivapithecus indicus*, provisional and partly hypothetical restoration after Pilgrim; *B, Dryopithecus fontani*, after Branco. (Figures adapted from W. K. Gregory.)

has taken the view that the genus *Sivapithecus* of the middle Miocene is very close to a line leading to the earliest known human types and also represents the gibbon group.

Of the forms in the middle and late Miocene stage the group of species gathered under the name of *Dryopithecus* has been held by a considerable number of investigators to stand nearest to man. In his admirable work on the evolution of the primates Dr. W. K. Gregory has recently considered *Sivapithecus* as closely related to *Dryopithecus* and a representative of the Simiine or orang-chimpanzee-gorilla group, rather than of the gibbons. The characters of the dentition and form of the jaw of *Sivapithecus* and *Dryopithecus* approach closely to those of the earliest types referred to the human group.

Taking the sequence of anthropoid forms as we know it, we find that in the earlier portion of Cenozoic time only relatively simple types are known as *Parapithecus* and *Propliopithecus* in which there are foreshadowed characters of both the typical anthropoid and gibbon types. In middle and late Miocene the gibbon becomes distinctly separated from the true apes, and there appears a group of several genera including characters of orangs, chimpanzees, gorillas and humans. As we proceed through the Cenozoic these groups become sharply defined, until by the end of the Pliocene they are clearly separated as at the present time, and in their development have passed through stages from some one of which the line of evolution to man many well have originated.

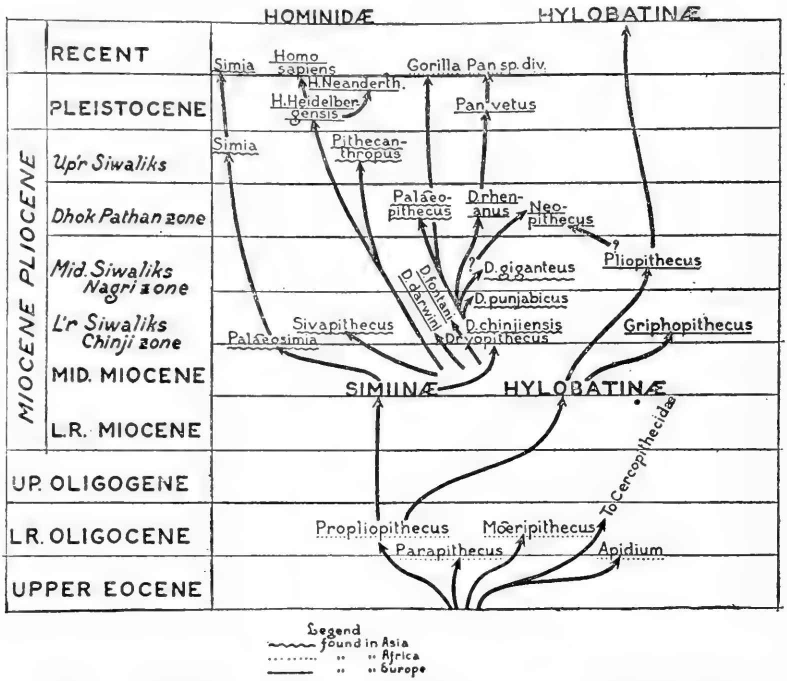


Comparison of Cheek Teeth from the Lower Jaw of Primitive Men and Anthropoids, crown views about three quarters natural size. *A*, gorilla; *B*, *Sivapithecus indicus*, after Pilgrim; *C*, *Pan* sp., after Miller; *D*, *Pan vetus*, adapted from A. Smith Woodward; *E*, *Homo heidelbergensis*, adapted from Schoetensack; *F*, *Homo sapiens*, molars of old female Australian black; *G*, *Homo sapiens*, from a Strandolooper Bushman. (Figures adapted from W. K. Gregory.)

A number of exceedingly fragmentary fossil specimens from America doubtfully referred to the anthropoid group are generally presumed to represent members of the Suidæ or pig family. Inasmuch as we are just beginning to obtain a knowledge

of the Pliocene, which is the critical period in consideration of earliest human history, and since the American assemblages in which the doubtful anthropoids appear are in many respects close to faunas of Asia and Europe in which anthropoids occur, it is not impossible that members of this group may yet be recognized in the latest Miocene and Pliocene of North America.

The extraordinary and interesting views of Dr. Florentino



GEOLOGICAL SUCCESSION AND PROVISIONAL LINES OF DESCENT OF MAN AND APES. (After W. K. Gregory.)

Ameghino concerning the possible origin of man by way of evolutionary stages leading through the South American platyrrhine monkeys seem not to be founded upon good logic, as these forms are fundamentally distinct in dentition and general skeletal structure from the Hominidæ or human family and from the whole old world group of anthropoids.

Of all the remaining unsolved problems of evolution one of the most important seems to rest in the working out of the later paleontologic history of the anthropoids, particular consideration being given to possible relationship of these forms to the earliest humans. As nearly as we can now determine, the Asiatic region has seen a large part of the evolution of the

apes, and contains also the oldest known remains of man. If man has been derived from anthropoids, the chain of missing links required to establish this biological relationship is presumably to be found there.

The 16,000-foot thickness of the Indian Siwalik series presents a most important volume of record in which anthropoid history is written, and no conditions for preservation of remains are more favorable than those of this region. It is not too much to expect that the next ten years of concentrated, well-organized effort in the Asiatic region will furnish as yet undreamed chapters in history giving early tendencies of evolution toward human characters, and evidence on the structure, relationships, habits and environment of earliest man. The undertaking will require much energy and large support, but when other problems of immediate urgency have been satisfactorily settled, it is to be hoped that this work may be carried through. It must be done by more intensive collecting in the known areas, and by a wide range of studies through other occurrences of the late geological formations found over large districts of the Asiatic region. There seems no doubt that some of the most important sources of material have as yet scarcely been examined. Concentrated effort by cooperation of a number of research institutions, or through considerable endowment by one institution operating through a series of expeditions would unquestionably contribute very largely to our knowledge of this most interesting phase of the evolution problem.

(*To be continued*)

SOME CHARACTERISTICS OF THE RAINFALL OF THE UNITED STATES

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Annual and Monthly Variability of Rainfall.—The amount of precipitation which occurs in a year is variable, because the rain-producing conditions, such as the number, intensity and paths of cyclones, and the general pressure distribution, vary more or less from year to year. A close study of the daily weather maps usually shows why a given station or district had a wetter or a drier year than normal. It is important for many persons, notably farmers and engineers, to be informed concerning the probable limits of such variations. The following table shows the ratios of the rainfalls of the wettest and driest years to the mean annual rainfalls for selected stations throughout the United States.[1]

Ratio of Wettest and Driest Years to the Mean Fall

Mean Fall Inches	Average of Wettest Year, Per Cent.	Average of Driest Year, Per Cent.
50–60	142	70
40–50	143	64
30–40	154	64
5–30	178	55

To state these relations verbally: an annual rainfall of nearly 180 per cent. of the mean may be expected in districts with mean annual rainfalls of 5–30 inches. In these same districts the rainfall of the driest years averages only slightly over one half of the mean. It will be observed that the departures from the mean average greater where the annual amounts are smaller.[2] Furthermore, there may be a succession of several years with an excess or a deficiency. During 1869–1903, considered by 5-year periods, a total of 119 stations in the

[1] Alfred J. Henry, "Rainfall of the United States, with Annual, Seasonal and Other Charts," *Bulletin D*, U. S. Weather Bureau, 4to, Washington, D. C., 1897, p. 41.

[2] See also A. R. Binnie, "On Mean or Average Annual Rainfall and the Fluctuations to which it is Subject," *Proc. Inst. Civ. Eng.*, Vol. 109, 1891–92, Pt. III., London, 1892 (average limits for wettest and driest years in North America are 141 per cent. and 68 per cent., as quoted by von Hann, "Lehrbuch der Meteorologie," 3d ed., p. 332).

"arid region" showed an excess in average annual rainfall, and 150 showed a deficiency.[3] It appears to be a general rule that years with precipitation above the mean are less frequent than those with precipitation below the mean. The plus departures are therefore greater than the minus departures.[4] Remarkable cases of great differences between the rainfalls of consecutive years are on record. Thus, on Mt. Hamilton, Cal., 90.1 inches of rain and melted snow were measured in 1884, and only 18.4 inches in 1885.[5] Many illustrations, although few as striking as this one, may be found in the records of the Weather Bureau.

The rainfall of any individual month may also differ greatly from the normal of that month. Many illustrations of this variability of the monthly means of rainfall might be given. The Weather Bureau records supply abundant data for the study of this subject. In a certain September, *e. g.*, when three cyclonic centers passed over the South Atlantic States, the average rainfall for the district was 9.47 inches, while in the same month in another year, when no storm center crossed the region, the average rainfall was less than one fifth (1.84 inches) as large.[6] It is always instructive to investigate the weather map conditions which give rise to unusually wet or dry months. The prevailing winds and the pressure distribution during a wet and during a dry winter month on the Pacific coast have been charted by Henry.[7] The abnormally rainy month was clearly due to the displacement, to the south of their usual latitudes, of the tracks of the low pressure areas. The amounts of rainfall along the coast north of San Diego were in most places over twice the normal, and in the Colorado region, where the monthly mean is less than 2 inches, this particular month gave over 10 inches. Unusually heavy monthly rainfalls over the plateau are almost always due to persisting cyclonic conditions west of the Rocky Mountains. In the dry month, the tropical high pressure system was abnormally far to the north, and the rainfalls averaged about half the normal amount. The

[3] William B. Stockman, "Periodic Variation of Rainfall in the Arid Region," *Bulletin N*, U. S. Weather Bureau, 4to, Washington, D. C., 1905, p. 6.

[4] An earlier table showing the mean annual deviation of rainfall at selected stations in the United States, as determined by Blanford's method, will be found in Gen. A. W. Greely's "American Weather," 8vo, New York, 1888, p. 154.

[5] See footnote, 1, p. 23.

[6] "American Weather," p. 148.

[7] See under footnote 1, Charts IV., VI., VIII., X., pp. 23–24. Also "Atlas of Meteorology," Text, p. 35, Pl. 24.

prevailing pressures and winds in a wet and a dry March in the Mississippi Valley have also similarly been considered by Henry,[7] and McAdie has charted the typical pressure distribution and flow of winds during a wet and a dry winter month in California.[8] The former had low pressure over the northwestern coast, with prevailing southerly (*i. e.*, rainy) winds, while the latter had high pressure over the northern Plateau, with prevailing northerly (*i. e.*, dry) winds.

The fluctuations of the monthly rainfalls at New York during the period 1871–1900 have been investigated by Wachenheim.[9] Three times in ten years a month occurs with less than 25 per cent. of its mean, usually in September and October. About twice as often the rainfall of a month is over 200 per cent. of the mean, mostly in summer and autumn. In 70 per cent. of all months the amount of rainfall is less than 50 per cent. above or below the normal. The annual means vary between 80 and 130 per cent. of the normal. The mean annual variability is only 9 per cent. At San Francisco it is 25 per cent.

Consecutive Days with and without Precipitation.—The maximum number of consecutive days that have been recorded as passing with, and without, rain or snow, is a matter of considerable general interest. These data do not, of course, indicate that such rainy or rainless periods occur annually, but they represent the maximum duration of these conditions within the years covered by the observations.[10] Over most of the country, the number of consecutive rainy days has been between 10 and 20, these conditions characterizing by far the larger part of the districts east of the Rocky Mountains except the southern Great Plains (Texas). On the northwestern coast (western Oregon), where the rainfall is heavy and the cyclonic activity is marked, more than 30 days in succession (30–40) have been rainy, while over a considerable area centering around the Great Lakes the number has been 20 to 30. The frequency of cyclonic rainfall in this latter section, and not the annual rainfall, clearly controls the conditions. The dis-

[8] Alexander G. McAdie, "The Rainfall of California," *Univ. of Cal. Publs. in Geogr.*, Vol. I., No. 4, February, 1914, Figs. 1–2, pp. 131–132.

[9] F. L. Wachenheim, "Die Hydrometeore des gemässigten Nordamerika," *Met. Zeitschr.*, Vol. 22, 1905, pp. 193–211.

[10] Mark W. Harrington, "Rainfall and Snow of the United States," *Bulletin C*, U. S. Weather Bureau, Washington, D. C., 1894, *Atlas*, Sheet XXII., Charts 9, 10; *Text*, pp. 28–29. (These charts were based on about twenty years of observations, and are the latest that are available. They are, therefore, not up to date, but are doubtless correct in general terms, and would not be materially altered by the addition of newer data.)

tricts of heavier annual precipitation north of the Gulf of Mexico have had fewer consecutive days with precipitation than the Lakes. Adjoining the district of the maximum number, on the northwestern coast, a considerable area, including part of northern California, eastern Oregon, most of Washington and Idaho, has had 20 to 30. The smallest number of consecutive days with rain or snow (less than 10) has occurred in southern California, over much of the Southern Plateau province, and over most of central and western Texas.

From two weeks to a month (15–30 days) have elapsed without precipitation over most of the Eastern Provinces, and from one month to two months (30–60 days) over most of the Plains, the Northern Plateau and the North Pacific provinces. The duration of rainless periods increases rapidly from all sides towards the arid districts of the southwestern interior, where over five months (150 days) have passed without rain or snow. Clearly, then, the duration of rainless periods is least where the rainfall is heavier, the distribution through the year is more uniform, and the cyclonic activity is greater

Droughts.—Long periods without rain are generally classed as droughts. The term connotes a long spell of dry, but not necessarily altogether rainless, weather, resulting in damage to crops. A clear-cut and comprehensive definition of a drought is, however, difficult to frame, for the reason that the effects depend so largely upon other factors than the deficiency of rainfall. Thus, the accompanying temperatures; amount of wind movement; character and condition of the soil; evaporation; cloudiness; stage of the crop, and other varying controls, enter into the problem. If a drought is arbitrarily expressed in terms of a deficiency in annual, or seasonal, or weekly rainfall of a certain percentage, it may appear that in two districts which have the same deficiency, the effects are different because the other controlling factors are not the same. Droughts of greater or less intensity may occur anywhere in the United States, but are more likely to be serious where the annual rainfall is small, and where cyclonic controls of precipitation are weak. Weather-map conditions during droughts as a whole show that the immediate meteorological controls are weakened cyclonic activity, or somewhat unusual cyclonic paths, or both. Special studies have been made of various severe droughts in the United States.[11] An economic aspect of droughts to which

[11] See, *e. g.*, A. W. Greely, *loc. cit.*, pp. 246–250; Alfred J. Henry, "Climatology of the United States," *Bulletin Q*, U. S. Weather Bureau, 4to, Washington, D. C., 1906, pp. 51–56; "Rainfall of the United States,"

special attention has recently been directed is that of their relation to the occurrence of forest fires. "A prerequisite of a forest fire is a drought."[12]

Additional Rainfall Data: Hourly Frequency of Rainfall.—A study of the distribution, intensity and frequency of rainfall brings out many interesting human relations, but the investigation involves much time and has so far received comparatively little attention in the United States.[13] The most complete studies of the details of rainfall in this country are those for Baltimore and for Chicago.[14] The economic importance of rainfall makes it highly desirable that many more such detailed studies should be undertaken. For example, if the hourly frequency of rainfall in the different months be known, it may be possible to plan outdoor work for the hours when there is the least likelihood of rain. Kincer has shown that over the Central Plains the greatest concentration of night rains occurs in the harvesting and threshing season, daytime rains being then comparatively infrequent.[15] The fact that the summer showers

Bulletin D, U. S. Weather Bureau, 4to, Washington, D. C., 1897, p. 18. A map of the eastern United States showing the frequency of dry spells in the months of April to September during twenty years was published in the *National Weather and Crop Bulletin* for May 4, 1915. The greatest frequency was in the Plains province; the least in the southern Appalachians.

[12] E. A. Beals, "Forecasts of Weather Favorable to an Increase of Forest Fires," *Proc. Second Pan Amer. Sci. Congr.,* Dec. 27, 1915, to Jan. 8, 1916, Vol. 2, Section 2: Astronomy, Meteorology, and Seismology, pp. 257–270, Washington, D. C., 1917.

[13] For a discussion of the rainfall data which are necessary in a full description of any climate, see J. von Hann: "Lehrbuch der Meteorologie," 3d ed., Leipzig, 1915, pp. 324–361. Also, "Handbuch der Klimatologie," 3d ed., Vol. 1, 8vo, Stuttgart, 1908, pp. 60–67.

[14] Oliver L. Fassig, "The Climate and Weather of Baltimore," *Maryland Weather Service,* Vol. II., Large 8vo, Baltimore, Md., 1907, pp. 159–237; Henry J. Cox and John H. Armington: "The Weather and Climate of Chicago," Large 8vo, Chicago, Ill., 1914, pp. 151–236. An earlier volume, still of importance in rainfall studies in the United States, is C. A. Schott, "Tables and Results of the Precipitation in Rain and Snow in the United States; and at Some Stations in Adjacent Parts of North America and in Central and South America," *Smithson. Contrib.,* No. 222, 4to, Washington, D. C., 1872; 2d ed., *ibid.,* No. 353, 1881. See also F. L. Wachenheim, "Die Hydrometeore des gemässigten Nordamerika," *Met. Zeitschr.,* Vol. 22, 1905, pp. 193–211. (Discussion of data for 1871–1900, including rain intensities for different districts.)

[15] Joseph B. Kincer, "Daytime and Nighttime Precipitation and their Economic Significance," *Mo. Wea. Rev.,* Vol. 44, 1916, pp. 628–633. (Hourly amounts and frequency are shown by diagrams. Three charts give the average precipitation for the United States in inches during the day, 8 A.M. to 8 P.M., and night, 8 P.M. to 8 A.M., for April–September,

are chiefly nocturnal means that evaporation is less than would be the case under sunshine. Daytime rains are dominant in the southeast and along the immediate Gulf coast. Over portions of the southeastern states only about 25 per cent. of the summer rainfall (April–September) falls at night, while on the Central Plains from 60 to 65 per cent., or more, falls during that time. At Columbus, O., 42 per cent. of the precipitation of the growing season (April–September) is recorded at night.[16] At New Orleans, La., in summer, the percentages of day rains as compared with those falling during the night range from 75 to 85.[17] Most of the summer rains are thunderstorm rains. At Galveston, Tex., convectional summer rains occur most frequently at night, and mostly in the latter part of the night.[18]

At Baltimore, the winter and spring months are characterized by a rather uniform distribution of precipitation throughout the day and night, in consequence of the uniformity of the cyclonic control, while in summer, a maximum occurs about 5 P.M., under the influence of thunderstorms.[19] At Chicago, also, the times of greatest hourly rainfall are related to the times of thunderstorm occurrence.[20] The hourly frequency of precipitation is greatest in the colder months.[21]

At Washington and New York the largest amount of rain falls between 2 and 4 P.M., and the smallest between midnight and 2 A.M. The rain frequency is greatest from 4 to 10 A.M.[22]

The mean hourly intensity of rainfall at New York, as given by von Hann, shows a maximum between 3 and 6 P.M. and a minimum between 3 and 6 A.M.[23]

Heavy Rainfalls in Short Periods.—Mean or average rainfalls do not often occur. An excess or a deficiency is much

1895–1914, and also the percentage of the average precipitation for the same months that occurs at night.)

[16] Howard H. Martin, "Hourly Frequency of Precipitation in Central Ohio, and its Relation to Agricultural Pursuits," *Mo. Wea. Rev.*, Vol. 46, 1918.

[17] E. D. Coberly, "The Hourly Frequency of Precipitation at New Orleans, La.," *ibid.*, Vol. 42, 1914, pp. 537–538.

[18] W. P. Stewart, "Midsummer Showers at Galveston, Tex.," *ibid.*, Vol. 41, 1913, pp. 1225–1226.

[19] *Loc. cit.*, footnote 14.

[20] *Loc. cit.*, footnote 14.

[21] See also George W. Mindling, "Hourly Duration of Precipitation at Philadelphia," *Mo. Wea. Rev.*, Vol. 46, 1918, pp. 517–520.

[22] "Tables of Average Hourly Precipitation at Washington, D. C. (1874–1891) and at New York (1870–1891)," *Mo. Wea. Rev.*, Vol. 20, 1892, p. 79. Also, *Met. Zeitschr.*, Vol. 9, 1892, p. 480.

[23] *Lehrbuch der Meteorologie*, 3d ed., p. 345. See also, A. W. Greely, *loc. cit.*, pp. 155–156.

more probable than the normal. Hence there is need of knowing something about the maximum amount of precipitation which has occurred, and which is therefore likely to occur again, or may even be exceeded. The maximum amount of water which dams, sewers and supply-pipes may at some time or other have to take care of is of vital concern to engineers. Farmers, too, are interested in this matter, because of the washing and flooding character of very heavy rainfalls.

Excessive precipitation may result either from short and heavy, or from lighter but longer continued rainfalls.[24] Rains of the former type do the most damage. These occur characteristically over the western mountain and plateau districts, and are therefore seldom recorded. The torrential downpour ("cloud-burst") on the distant, uninhabited mountain slope; the sudden rise of a stream in its narrow canyon; the rush of the flood downward with irresistible force—these are familiar phenomena to many who have sought their livelihood in that rugged country. In the eastern United States, excessive rains of this general type occur chiefly in summer; are associated with thunderstorms or with West Indian hurricanes, and are found chiefly along the southern Atlantic and Gulf coasts. Rains of lighter intensity and of longer duration, of the second type mentioned above, occur in connection with general storms of unusual development, and are therefore found in the sections most frequently crossed by such storms, in the eastern and northeastern portion of the country, and on the northern Pacific coast. As pointed out by General Greely, the conditions which give rise to such excessive rainfalls are not likely to last long. These heavy downpours are therefore usually over within a day or so.[25]

Where the line between damaging and favorable rainfalls shall be drawn depends upon a large number of factors, such as topography, soil, condition of crop, etc. Complete data concerning excessive rainfalls for the year, month, day and shorter periods, are regularly published in the *Annual Reports of the Chief of the Weather Bureau* and in the *Monthly Weather Review*. Numerous other tables of heavy precipitation, and several discussions of these data, have been published in recent years.[26]

[24] A. J. Henry, "Rainfall of the United States," *Bulletin D*, U. S. Weather Bureau, 1897, pp. 52–54.

[25] A. W. Greely, *loc. cit.*, p. 148.

[26] See, *e. g.*, A. W. Greely, *loc. cit.*, pp. 144–150 (details of excessive rainfalls up to date of publication); Mark W. Harrington, *loc. cit.*, Text, pp. 27–28, 59–80; *Atlas*, Sheet XXII., Map 8 (discussion of heaviest rain-

In a general description of climate, the actual "record" rainfalls are of no special concern. The maximum changes as the length of the period of observation lengthens. "Records" are thus constantly being "broken." The absolute maximum hitherto noted is, therefore, a rather accidental matter at best, and it is hardly worth while, in a general account, to remember single "records" which are, at any moment, likely to change. For the present purpose, broad generalizations, easily remembered, are sufficient.

As a convenient rough-and-ready classification the following rainfalls may be termed excessive: 10 ins., or more, in a month; 2.50 ins., or more, in 24 consecutive hours; 1 in., or more, in an hour. It must, however, be noted that these amounts are often reached and exceeded, and are in no way to be regarded as unusual in many sections of the country. They are especially likely to occur along the southern Atlantic and Gulf coasts in the warmer months, and on the Pacific coast in winter. An examination of the available data regarding the heaviest rainfalls in the United States leads to the following simple general statement, which covers the ground fairly satisfactorily and will need no essential modification as the length of the period of observation increases. An average of 1 in. a day, for 30 days, giving 30 ins. in a month, is not often exceeded, although there are a good many cases of still heavier monthly rainfalls, and one case of over 70 ins. (Helen Mine, Cal., January, 1909). A fall averaging 1 in. an hour, for 24 hours, covers the heaviest daily rainfalls thus far recorded, the absolute maximum being 22.22 ins., at Altapass, Mitchell Co., N. C., July 15, 1916. It is impossible to give any rate of rainfall covering, in a similar simple way, the amount of precipitation in spasmodic, torrential downpours which may be over in half an hour, or in even less time. In a "record" cloud-burst (Campo, Cal., August 12, 1891) 11.50 ins. fell in 80 minutes. This was at the rate of a little over 8.50 ins. an hour, continued for 1 hour and 20 minutes. In some of these "cloud bursts" the rate has actually been as high as 16–18 ins. an hour, but

falls, including heaviest rainfalls at selected representative stations for year, month, 72, 48 and 24 hours, with tables); A. J. Henry, *loc. cit.*, pp. 52–58; "Summaries of Climatological Data by Sections," *Bulletin W*, U. S. Weather Bureau, 1912, and later reprints of various sections. A recent discussion and tabulation of data, mostly for the period 1896–1914, will be found in Adolph F. Meyer, "The Elements of Hydrology," 8vo, New York, John Wiley and Sons, 1917, pp. 64–187. (Includes data for typical excessive rain-storms; illustrated by numerous curves and charts.) See also C. A. Schott, *loc. cit.*, footnote 14.

continued for very short periods. In view of the "patchiness" of the records of heaviest rainfalls, it hardly seems worth while to chart them for the country as a whole, although Harrington prepared such a chart in 1891.[27] From this chart it appears that, not taking account of the mostly unrecorded local cloudbursts of the West, daily rainfalls approximating and even exceeding 10 ins., have occurred over a relatively narrow strip along the southern Atlantic and Gulf coasts, and were associated with the passage of West Indian hurricanes. To the north and west the maximum daily rainfalls as a whole decrease in amount, increasing again on the northern Pacific coast, but without equalling those of the southeastern sections.

Secular Variation in Rainfall: Instrumental Records.—Popular belief in a "change" of climate goes back to the early decades of the settlement of the United States, and frequent mention of the subject occurs in the literature. In the '70's and early '80's a widespread interest developed in the question because of the impression, which rapidly gained ground, that the building of railroads, the construction of telegraph lines and the ploughing of the soil over the western Plains were gradually bringing about a progressive increase in the rainfall over those sections of the country. Popular interest in the matter naturally led to a critical examination of the then available rainfall records, and several studies were, at that time, made along this line.[28] No definite evidence of any progressive secular variation in rainfall was found, in these, or in other early investigations of a similar sort.[29]

It is upon the evidence furnished by accurate instrumental records, and not upon tradition, or human memory, or uncertain evidence of other kinds, that reliable conclusions in this matter must be based. The period covered by rain-gauge rec-

[27] *Loc. cit.*, footnote 10.

[28] See, *e.g.*, C. A. Schott, *loc. cit.*; H. A. Hazen, "Variation of Rainfall West of the Mississippi River," *U. S. Signal Service Notes*, No. VII., 8vo, Washington, D. C., 1883, p. 8; also "Droughts in Kansas and Texas and Secular Variation in Rainfall," *Mo. Wea. Rev.*, Vol. 15, April, 1887, p. 119; Mark W. Harrington, *loc. cit.*, *Text*, pp. 19–20; *Atlas*, Sheet XXII., Map 4; J. D. Whitney, "Brief Discussion of the Question whether Changes of Climate can be brought about by the Agency of Man, and on Secular Climatic Changes in General, with Special Reference to the Arid Region of the United States," *The United States*, Suppl. I., Boston, 1894, Appendix B, pp. 290–317.

[29] See, *e.g.*, "Supposed Recent Changes in Climate" (by W. Upton and others), *Amer. Met. Journ.*, Vol. 7, June, 1890, pp. 79–81. (The records at New Bedford, Mass., from 1813, and at Providence, R. I., from 1831, show no progressive change in rainfall, but there are indications of a periodicity of about twenty years).

ords in the United States is a comparatively short one. Few observations go back of 1850, and most of them date from later than 1870. There have thus far been few noteworthy studies of these records from the viewpoint of their relation to climatic "changes." The more numerous discussions of limited scope are mostly based on insufficient data. Abundant material for investigations of this sort is now available.[30]

In the Temperate Zones most of the rain and snow comes, directly or indirectly, in association with general cyclonic storms. As the paths, numbers and intensities of these storms vary more or less from year to year, it is inevitable that the precipitation of any year, or of any month, may differ considerably from the general average for that period. Even a single heavy thundershower, or a well-developed general rainstorm may, for example, raise the total rainfall for a month 2 or 3 ins. above the normal. Such annual and monthly fluctuations of rainfall are well-known. They may result in giving a single year or month, or a series of them, wetter or drier than the average. The question whether there is any tendency towards a progressively decreasing or increasing rainfall anywhere in the United States, and whether there is any evidence of a periodic variation or oscillation in rainfall has in recent years been somewhat fully discussed by Professor A. J. Henry, and by Professor Eduard Brückner.

Henry plotted the "progressive averages of precipitation" for certain stations in southeastern New England, in the upper Ohio Valley (both for the years 1834–1896), and in the middle Mississippi Valley (1858–1896).[31] A rough periodicity of about nine years appears in the Ohio Valley curve. The curve for the middle Mississippi Valley shows little indication of periodicity. The New England curve shows a noticeable increase in rainfall, apparently a local phenomenon, from about 1845 on, with a climax in 1888–1889 (a drought period in 1880–1882 being excepted). It is apparent that the three curves are not in agreement as regards their periods of maximum and minimum. A later study of the departures from the normal of the annual rainfalls for all districts of the United States in the period 1887–1911 (25 years) "lends no color to the theory of a cycle in precipitation."[32] During the 25-year period under dis-

[30] See, *e. g.*, "Summaries of Climatological Data by Sections," U. S. Weather Bureau. (These Summaries contain the monthly and annual amounts of rainfall for each year throughout the period covered by the observations).

[31] Alfred J. Henry, *Bulletin D*, pp. 18–24, Pl. II.

[32] A. J. Henry, "Secular Variation of Precipitation in the United States," *Bull. Amer. Geog. Soc.*, Vol. 46, March, 1914, pp. 192–201.

cussion, the tendency seems to have been towards years of deficient precipitation, although years of abundant rainfall were interspersed. Curves for selected stations in New England, the interior, the western Gulf, and North Carolina (1879–1911) show no "approach to uniformity of distribution in time or space." For the period and the districts under discussion, there were about equal numbers of dry and of wet years. Conditions favorable for unusually heavy rains over extended areas are apparently exceptional. Rainfalls close to or slightly below normal are rather to be expected.

Brückner has shown that over the world as a whole warmer and drier periods alternate with periods which are cooler and moister in an oscillatory cycle of about 35 years from maximum to maximum.[33]

In the case of the United States, curves are given for stations in the upper Ohio Valley, the central portion of the Mississippi Valley and for New England. The rainfall for each year is taken as the average of the 10 years of which it is the center, *e. g.*, for the year 1835, the average of the years 1831–40 is taken. In all parts of the world which are represented in the curves, except New England,[34] there was a maximum of rainfall about 1845–50; a minimum about 1860–70; another maximum in the early '80's, followed by a decrease until the end of the last century. From the minimum of 1836 to the minimum of 1871 there were 35 years, and between the maximum of 1848 to that of 1882 there were 34 years. At present, there is a cool and moist period, the middle of which is to be looked for about 1920. These oscillations have been traced back over 700 years in Europe, and, in Brückner's opinion, there is no doubt that they will continue. The size and value of crops; movements of population, and other economic consequences have been shown to depend upon these cycles. Thus, the maximum of rainfall about 1880 was followed by the "boom" on the High Plains, and the collapse of the same "boom" occurred when the

[33] Edward Brückner, "Klimaschwankungen seit 1700, nebst Beobachtungen über die Klimaschwankungen der Diluvialzeit," Vienna, 1890, pp. 324; "Zur Frage der 35-jährigen Klimaschwankungen," *Pet. Mitt.*, Vol. 48, 1902, pp. 173–178; "Klimaschwankungen und Völkerwanderungen im XIX Jahrhundert," *Internat. Wochenschr. f. Wissenschaft, Kunst und Technik*, 1910, March 5, pp. 15 (Berlin); "The Settlement of the United States as controlled by Climate and Climatic Oscillations," *Memorial Volume of the Transcontinental Excursion of 1912 of the Amer. Geog. Soc. of New York*, Large 8vo, New York, 1915, pp. 125–139.

[34] In the case of New England, the recent maxima came in 1869 and 1889, the conditions being different from those inland because of marine control.

succeeding dry period came on. Obviously, oscillations of rainfall will have their most far-reaching effects in regions over which the normal precipitation is barely enough for the ordinary needs. Here a fluctuation on one side or the other of the mean is of critical importance. Brückner has shown that in the most continental climates the difference between the maximum and the minimum rainfalls may amount to 25 per cent., or even 50 per cent. or more. The oscillations in the level of Great Salt Lake show no permanent change. The waters of the lake rise and fall with a periodicity which agrees in general with the Brückner 35-year cycle. After the close of the dry period following the middle of the last century, the lake rose more than 12 feet up to about 1880, its maximum coming during a wet period. Then it fell again during the next dry period, and rose during the present wet cycle.

Secular Variations in Rainfall: Non-instrumental Evidence.—Climatologists who take a broad view of their subject are interested in any facts which may throw light on the question of secular variations in rainfall. They agree, however, in the conviction that non-instrumental evidence is to be regarded as in a wholly different category from that of actual rain-gauge records in that the former can not possibly be subjected to the same rigid analysis and scrutiny as is the case with the latter.

Within the last few years, Professors A. E. Douglass and Ellsworth Huntington have made a study of the "rings" of trees in Arizona and in California, it being assumed that the thickness of the annual layers of tree-growth gives an approximate measure of the annual amount of precipitation. Douglass has measured the rings of yellow pines on the northern Arizona plateau, and finds a correlation between tree growth and certain meteorological cycles.[35] By means of an empirical formula, a test was made covering a period of over 40 years for which actual rainfall records are available, and it was found that the rings gave a measure of the rainfall with an average accuracy of over 70 per cent.[36] Indications of periods of 11.4,

[35] A. E. Douglass, "Weather Cycles in the Growth of Big Trees," *Mo. Wea. Rev.*, Vol. 37, 1909, pp. 225–237; "A Method of Estimating Rainfall by the Growth of Trees," *Bull. Amer. Geog. Soc.*, Vol. 46, May, 1914, pp. 321–335; "Pine Trees as Recorders of Variations in Rainfall," *Astron. and Astrophys. Soc. Amer.; Bull. Internat. Insti. Agri.*, abstract in *Quart. Journ. Roy. Met. Soc.*, Vol. 39, July, 1913, pp. 244–245. F. E. Clements and A. E. Douglass: "Climatic Cycles," *Yearbook Carnegie Institution*, Washington, D. C., 1918, p. 295. (Discusses coincidence of drought in the Southwest with years of maximum sunspots, and mentions further tree-ring examinations to be made with this in mind). See also footnote 37, later.

[36] In the case of the older trees, certain corrections were applied.

21 and 33.8 years, as well as of still longer fluctuations, were found. The last crest of the 33–34 year period, about 1900, can be correlated with the Brückner period above referred to.

The results obtained by Douglass have been included by Huntington in a very considerable investigation of the various kinds of evidence of climatic "changes" during the past 3,000 years in the arid southwest. This investigation involved a study of the rings of the "Big Trees" of California; and of prehistoric ruins; archeological remains; strand lines, dunes and alluvial terraces in southern Arizona and New Mexico.[37] A comparison of the curves showing the rapidity of growth of the "Big Trees" with curves previously plotted, illustrating changes of climate in Central and Western Asia, leads Huntington to the conclusion that there is a correspondence between them back as far as 1200 B.C., the agreement being especially pronounced during the period 300–1000 A.D. There are, however, also cases of a lack of correspondence between the curves. The archeological and physiographic evidence seems to Huntington to indicate three periods during which a much larger population was living in the southwest than seems to be possible at present, owing to the existing deficiency of water supply. These three population eras were about 1200 B.C., and in the seventh and thirteenth centuries A.D., and correspond with three long wet periods suggested by the studies of the tree rings made by Douglass and Huntington.

The Climatologist's Attitude regarding Non-instrumental Evidence of Climatic Changes.—Climatologists as a group do not feel competent to weigh such facts as those adduced by Huntington and others regarding climatic oscillations long before the days of instrumental records. They realize that the proper understanding and critical analysis of botanical, archeological and physiographic evidence requires a degree of technical knowledge which is usually not a part of their own scientific equipment. Therefore it must be left to the experts to

[37] Ellsworth Huntington, "The Fluctuating Climate of North America," *Geogr. Journ.*, Vol. 40, September–October, 1912, pp. 264–280, 392–411 (abridged and reprinted in *Smithson. Inst. Ann. Report for 1912*, Washington, D. C., 1913, pp. 257–268); "The Shifting of the Climatic Zones as Illustrated in Mexico," *Bull. Am. Geogr. Soc.*, 1913, Vol. 45, 1–12; *Geogr. Journ.*, Vol. 41, June, 1913; "Secret of the Big Trees, Yosemite, Sequoia and General Grant National Parks," *Pub. U. S. Dept. of the Interior*, 1913, 24 pp., 14 figs.; "The Secret of the Big Trees," *Harper's Mag.*, July, 1912. See especially "The Climatic Factor as Illustrated in Arid America," by Ellsworth Huntington, with contributions by Charles Schuchert, Andrew E. Douglass and Charles J. Kullmer. *Publ. of the Carnegie Inst. of Washington*, No. 192, 4to, Washington, D. C., pp. iii and 341.

weigh this evidence and to determine its value. In connection with this, it may be stated that these experts are by no means unanimous in their views. It has, *e. g.*, been pointed out that the growth of tree rings may be affected by many conditions other than the annual rainfall. The distribution of precipitation through the year exercises a more critical control than the annual amount, while the age of the tree; normal cycles in the tree's growth; insect and other pests, often themselves coming periodically; overcrowding; the loss of shelter, and other factors must be taken into account. Furthermore, the determination of the proper "correction factor" in plotting the curves may not be as simple a matter as it seems. The fact that the "Big Trees" have continued to thrive for 3,000 years has been taken to indicate a remarkable uniformity of climatic conditions, rather than a series of oscillations. Again, there is opposition among geologists to the view that variations in erosion and in lake levels, due to variations in rainfall, furnish the proper explanation of the conditions which have been observed in the dunes, strand lines and alluvial terraces. In a region of active mountain growth, like the southwest, elevation of the land may explain the facts whose interpretation has been sought in climatic change. Lastly, the archeological evidence is by no means regarded as conclusive by all the experts. Thus, J. W. Fewkes and others believe that long-continued prehistoric irrigation, leading to increasing salinity of the soil, was perhaps more potent in causing human migrations than human enemies or increasing aridity.[38] Migration in search of firewood, and invasions of enemy tribes, as well as a reduction in the fertility of the soil, may help to explain these prehistoric changes of population.

In the face of such conflicting testimony on the part of the experts, the conservative climatologist may well remain open-minded on this whole question.

[38] J. W. Fewkes, 28th *Am. Rept. Bur. Amer. Ethn.*, 1906–07 (1912). There is abundant literature on the archeology of the southwest. See, *e. g.*, the following recent publications: E. L. Hewett, J. Henderson and W. W. Robbins, "The Physiography of the Rio Grande Valley, New Mexico, in Relation to Pueblo Culture," *Bulletin 54, Smithsonian Inst., Bur. Amer. Ethn.*, 8vo, Washington, D. C., 1913, pp. 76 (pp. 41–70 on climate and the evidence of climatic changes. A progressive desiccation of the region since the beginning of the pueblo and cliff-dwelling period is thought to be indicated, but the change in population may possibly be ascribed to other causes). Harold S. Colton: "The Geography of Certain Ruins near the San Francisco Mountains, Arizona," *Bull. Geogr. Soc. Phila.*, Vol. 16, April, 1918, pp. 1–24. (Discusses the ruins as affording evidence of climatic oscillations. "The question can not be finally settled until much more work has been done in the pueblo region").

MAN AND HIS NERVOUS SYSTEM IN THE WAR

BEING SOME REFLECTIONS UPON THE RELATION OF AN ORGANISM TO ITS ENVIRONMENT. II

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MAN IN HIS RELATION TO HIS ENVIRONMENT. MAN'S REACTION TO SOCIAL AND POLITICAL CONVENTIONS

THESE considerations must be urged as a justification for the attempt of a physiologist, representative, loyal though confessedly unorthodox in many particulars, of a science that has concerned itself far more with internal organization than with the effects of, or reaction to conditions in the environment, to go back along the road of the naturalist which he traveled as a student, to set forth in brief the general features of man's reaction to war and war conditions from the point of view of the organization of the nervous system. For it is through the nervous system that the reactions which I wish to describe have arisen. In order to do this, we may first look a little more closely at the manner of organization of the nervous system and some of the changes it has undergone in the course of organic evolution.

The possibility of affecting the organism through its nervous system has been mentioned. The property of irritability or excitability is highly developed in nervous tissue. And its sensitiveness, as was previously stated, is further increased by the development of highly specialized sense organs at the periphery. The eye and ear are familiar examples of such sense organs. A sense organ has been defined as a mechanism for decreasing the threshold of a stimulus, *i. e.*, a mechanism for making the organism more sensitive to a given form of energy in the environment than it would otherwise be. A very intense light or an extremely loud sound would be necessary to stimulate a nerve trunk directly, but through the mechanism of the eye or the ear, almost any measurable intensity of light or a very slight sound may set up a nerve impulse which, on reaching the central system, is interpreted as sight or hearing. The nervous system, through its peripheral sense organs, is more sensitive to some agents in the environment than the chemical

mechanisms of the body. And the greater the number of sense organs or the higher their degree of development, the more sensitive does the organism become. Some animals have more highly developed sense organs of a particular kind than man, as for example, dogs, which have a more acute sense of smell. Other forms probably have sense organs for the perception of certain agents in the environment which man is unable to appreciate without the aid of laboratory instruments. But the fact remains that man is sensitive to many manifestations of energy in the external world.

Mere sensitiveness to agents in the external environment constitutes but one side of the picture. The reaction of the organism to the agent in the environment is still to follow. And given the same set of external conditions, animals of different species may react in different ways, or different individuals of the same species may exhibit considerable variation.[1] In general the lower forms of vertebrates exhibit the greatest degree of uniformity of reaction. And often the first time a young animal reacts, its response is similar in every way to that of an adult animal which has given this particular response many times. Whitman calls such responses instinctive responses and we may refer to his graphic description of the action of a young puppy when it first takes food as an illustration. He attributes their peculiar manner of execution to the (internal) organization of the animal; and going a step farther, we may recall Magendie's statement that instinctive responses are dependent upon the organization of the nervous system. A little further up in the animal scale, the element of a choice between two responses may enter into the problem, and we have the origin of the possibility of intelligence. Whitman's description[2] of the reactions of three different species of pigeons, the wild passenger pigeon, the little ring-neck and the common dove-cote pigeon, on finding the eggs gone from the nest shows what a narrow boundary separates instinct from the beginnings of intelligence. The outstanding feature of the deportment of the lower organism is the narrow limits of variation in any given reaction under a given set of conditions.

But narrow limits of variation in a response are not confined to lower vertebrates. New-born mammals usually execute the first few respiratory movements in essentially the same way, using essentially the same motor nerves and muscles as adults. The first swallowing movements are also biologically adequate, resulting in the entrance of food into the stomach.

[1] See *Columbia University Quarterly*, 1918, XX., pp. 150–152.

[2] *Loc. cit.*, pp. 334–335.

The mechanism for each of these movements is laid down in the sense organs, the afferent nerves, the central nervous system, the efferent or motor nerves and the effectors—the muscles and glands to which they go.

There are two features of this type of movements that are worthy of remark. The first is their high degree of efficiency. In the higher organisms the movements of respiration go on for hour after hour, year after year, always keeping oxygen in the blood and removing carbon dioxide from it as long as life lasts. Few mistakes are made, partly for the reason that the machinery is so highly organized and efficient that mistakes do not often occur, and partly for the reason that when mistakes are made, they are sometimes fatal. The young necturus or the young fish soon leaves the confines of home and shifts for itself. Since its reactions are essentially the same as those of an older fish or an older mud puppy, it catches its food and seeks shelter in the way of all its tribe. And if the young fish does make a mistake, there are plenty more from the same home or other similar homes to make up for the ones that fall into error. Learning, while possible in many of these forms, does not fundamentally change their general behavior. Reactions of this type possess the merit of that form of efficiency which always gets things done in the same unchanging way, and which results from a high degree of organization.

Such efficient and unchanging types of reactions, however, are not without disadvantages. When we compare the movements of respiration and swallowing with the movements of the hand, certain deficiencies of the former type may be brought out. The child can not use its hands in early life with as great precision as it can swallow or breathe. Long periods of instruction and some years of growth are required before it can acquire facility in writing or bricklaying or in using a typewriter or playing a piano. Probably the time never comes when it can do any of these things with as few mistakes as it makes in breathing or swallowing. From this point of view, these reactions never become as efficient as the reactions of breathing or swallowing. And, whereas all that live, breathe and swallow, probably no one individual can learn to write and lay bricks or use the typewriter or play the piano with equal facility. But while these reactions must be learned, and never become as efficient as breathing or swallowing, they offer an avenue of escape from the monotony of the life of the fish and the mud puppy, or the mere occupations of breathing and swallowing. The nervous mechanisms for the control of the movements of the hand are not as highly organized as the mech-

anism for the control of swallowing and respiration, and arise later in the course of organic evolution. A profound student and philosopher of the nervous system, Hughlings Jackson, called attention to this fact, and remarked that, if all parts of the nervous system were as highly organized as the mechanism for the control of respiration, there would be little hope of the acquisition of new attainments. This statement is worthy of some thought on the part of those who have insisted in recent years that the hope of man lay in a higher degree of organization and efficiency. Nature did not stop with the production of highly efficient nervous systems, but went on to other higher types. And, disconcerting as the discovery may be to the apostles of a high degree of organization, there is scarcely any fact in nature better established than the fact that the evolution of the higher forms has led to the production of a nervous system some of whose mechanisms are not as highly organized as are those of lower animals, but which permit of new attainments by the method of "muddling through" to proficiency if proficiency is ever attained. Man's nervous system permits of muddling through to proficiency in more directions and in more reactions than that of any other animal. And since it is the common observation of many that not all men can muddle through to equal proficiency in all directions, but that one man can do some things better than he can others, we have the existence of those variations which constitute individuality. Following a second line of evidence—that of the course of evolution of the nervous system— we come again to the same conclusion at which we arrived after the survey of the chemical mechanism of coordination—namely, Bergson's statement that life tends toward individuality.

Man manifests individuality in his mental processes quite as much as he does in motor reactions. Often, in fact, his motor reactions follow only as the result of his mental processes. Probably it is more through his individuality in thought rather than of mere action that he has come into conflict, whether for good or evil, with his fellows.

Various means have been adopted in the past in the attempt to limit the exercise of man's individuality through the setting up of conventions of various kinds. Conventions have often been set up to preserve the better things of life and to prevent a falling back to a lower standard. The motive has often been of the highest kind. Other conventions have been set up from motives of self interest to guard the interests and privileges of a small group against the assaults of the multitude. The ultimate effect of conventions of this sort has often been illustrated

in the course of human history. The most typical and far-reaching form, so far as its effects on the general intellectual life of the community is concerned, has been the particular sort of convention set up in a theocracy such as that of ancient Egypt or Babylon. The story is best given in the words of a historian.[3]

In substance, too, the evolution of the two civilizations is strikingly alike. Smaller communities of varied racial origin are slowly welded together under conquering chiefs, whose power is supported by a religious system, also slowly elaborated, in which the divine and human are so closely intertwined that ultimately in each case the ruler and the leading deity are practically identified. In each case a lower and upper kingdom are finally amalgamated round a central city, in the one case Memphis, in the other Babylon, some way removed from the river's mouth. In each case, the priestly order, in close alliance with the throne, devotes itself, in opulence and leisure, to the elaboration of the theological system by a study of the heavens. In each case these observations give valuable material and stimulus to later science, and specially in two spheres of their activity results are achieved of the highest lasting service to mankind. To their beginnings in measurement and calculation we owe most of our common units of time and space, and to their invention of writing probably the foundation of our own. It is these written records which have revealed them to us, and formed to them also one of the strongest links between successive generations. In each case, too, we note in the earliest periods an extraordinary freshness and fineness in their artistic work which is similarly marred later on in both by the extravagances of an imperialistic spirit and the rigidity of convention.

As physiologist, I would be inclined to characterize this kind of convention as an attempt to reduce the action of the neencephalon—the newer part of the brain by which man has attained his individuality—to the level of the relatively unvarying action of the palæencephalon which governs the responses of the fish and the mud puppy and presides over respiration and swallowing, by mere fiat of man. But not all men in the world came under the dominance of Egypt or Babylon, and the Egyptian and Babylonian empires did not last forever. Other men in other parts of the world were unbound by convention of this sort and man's progress continued for a time in more favorable surroundings.

Greece was the next place in which the light of man's intellect flamed up and we read in such a work as Professor Bury's "History of the Freedom of Thought"—a work worthy of being read by every student of science—that reason was free in Greece and Rome. Yet convention did not wholly pass them by. And again in Greece the origin of the convention can be traced to the desire of a small group to protect their own interests or to conserve their own source of revenue.

[3] Marvin, "The Living Past," pp. 32–33.

The priestcraft of the earliest times met with difficulties in gaining the ascendancy and in maintaining it when it was once obtained. Perhaps the clearest picture of the nature of these difficulties and of the attempt to overcome them by building up a system of convention for mostly sordid motives is to be found in the history of Greece. Homer, as A. W. Benn[4] remarks, treated the gods in a humorous, joking sort of a way which no organized priestcraft would have permitted. But at that time no organized priestcraft existed, and a certain sceptical attitude did no particular harm. But, as soon as a priestcraft began to develop, the need for funds arose. No priestly hierarchy could get money from the populace so long as it had back of it only the sort of gods Homer described. And since traducers of the gods interfered with the general scheme of financing the priestcraft, such traducers had to be dealt with. Since the opportunity for casting aspersions on the gods ended with the life of the irreverent individual, it seemed a simple solution of the problem to kill the irreverent individual. This was attempted in the case of Anaxagoras, who held unorthodox views concerning the nature of the sun and moon.[5] It seems probable that Anaxagoras escaped death for blasphemy, and the system never worked out as well at Athens as it did in other countries in later years. But it was soon found that the death of one individual did not wholly solve the problem, and it became necessary to make the attack on it in a systematic way. Legal sanction for the execution of heretics and blasphemers was obtained, and the power of the priestcraft increased. Everything seemed to be going well.

As time went by, however, some began to suspect that the method of the priestcraft was not, after all, the best method of approaching the solution of the problem. To some, it seemed best to eliminate gods of questionable character and get along with those of known worth. Scourging the money-changers from the temple is one concrete instance of the application of this method applied to more mundane affairs. This latter method of approach did not, however, meet with universal favor, especially in official quarters, and it was only after the lapse of generations that the Greek gods and others of their ilk were eliminated. The two methods persist to-day, and usually the weight of official opinion has been thrown in on the side of the first method. In general, mankind has been divided into two great groups, one of which has been engaged in "putting

[4] "Early Greek Philosophy," p. 7, New York.

[5] Benn, *loc. cit.*, p. 75.

things over" and the other composed of those who have been told that it is impolite, or even impolitic, to make a fuss.

The two groups have sometimes, but not always, been divided on the basis of age. A quotation from the work of a student of Greek drama is in point here.[6] Sheppard, in speaking of the age of Euripides, remarks concerning affairs at Athens:

> Superstition still prevailed. Therefore the Enlightenment was salutary, and was necessarily disruptive. It was also inevitable. When the fathers think the Age of Reason is achieved, the sons may be trusted, if they are of good stock, to see that it is still far off. The revolution in thought, which Aristophanes deplored, was the legitimate offspring of the Periclean age, though, like most children, it scandalised its parent. From the time when Pericles became supreme, Athens was the center of Greece. Her citizens travelled, and saw the customs of many nations. In the assembly, and the law-courts they needed the arts of rhetoric, even before teachers came from Sicily to teach the argument. All men who had ideas found listeners and ready talkers in Athenian gymnasia, and the seeds of opinion ripened after the sowers had perhaps been sent about their business. Everything, divine and human, had to stand the test of criticism.

Much the same idea is expressed by James Russell Lowell in his "Ode for the Fourth of July, 1876":

> Poets, as their heads grow gray,
> Look from too far behind the eyes,
> Too long experienced to be wise
> In guileless youth's diviner way.

The blindness to the ways of youth is still with us. Free in thought though we may boast ourselves to be, there are yet few among the elders who have remained sufficiently free from convention to regard "guileless youth's diviner way" in its true light. For it, too, is a result of evolution, and upon its continuance our progress depends.

The problem of the autocratic ruler has not been very different from that of the priestcraft, and the method of attempted solution has been very much the same. There grew up in "that Divinity that doth hedge a king" an elaborate system of convention which tended to limit the expression of the individuality on the part of the subjects of the kingdom. The most elaborate survival of such a form of convention is the taboo of the South Sea Islands, since it could scarcely survive in any society in which the elaborate claims of the ruler were subjected to any sort of critical inquiry. Conventions of this sort flourish best among peoples whose general mental processes are not characterized by any high degree of individuality. But facts and theories of this nature fall in the province of the

[6] Sheppard, "Greek Tragedy," p. 124.

social anthropologist, and his opinion is entitled to a hearing. Both physiologist and anthropologist have little hesitancy in regarding the taboo as superstition. Going on from this point, the social anthropologist recognizes that without the aid of superstition to maintain them, some of our common political and social institutions would have been modified or have collapsed long ago. The institutions of government, of private property, of marriage and even of respect for human life were originally founded upon superstition, and maintained by it long after their foundation.[7] Superstition has not been without its beneficial results, since some of these institutions have been worthy of preservation. But one may hope that eventually all of these institutions will be placed on a rational basis and worked out in accordance with the principles of human reason.

The Justification of the Freedom of Thought

The conventions set up by the ancient priestcraft and the kings of the ancient monarchies tended to limit the freedom of thought. Other conventions have tended toward the same end, and man has, sooner or later, rebelled against them. Bloodshed has been the price paid for breaking convention and securing freedom of thought. Much discussion has centered about the question, and discussion is likely to continue for some time to come. As a biologist, I would consider that the question of freedom of thought is bound up with man's nervous system. The historian finds a justification for the freedom of thought, not "on the conception of natural right," but "on the assumption that the progress of the race, its intellectual and moral development is a reality and is valuable."[8] Biology comes to the aid of this assumption; and, from the point of view of organic evolution, it is not so much an assumption as a fact. Mental processes, as Burdon-Sanderson stated,[9] are a part of the specific energies of the organism, and should, on that ground, be included in the subject-matter of physiology. Referring back to the point of view of the physiologist, we may suppose that, ordinarily, mental processes go on for the good of the individual. A man's thoughts become a part of the general activity of his nervous system, and can not be unreasonably limited without interfering with his internal development, which has arisen, and, let us hope, will continue, as the result of processes of organic evolution. As Herbert Spencer expresses it, "a man's thoughts are as children born unto him, which he may not will-

[7] Frazer, J. G., "Psyche's Task," London, 1913.
[8] Bury, *loc. cit.*, pp. 240–241.
[9] *Loc. cit.*, p. 469.

ingly let die." But mental processes, like other processes in the body, may become perverted, and we may have mental disease as a result. Such diseased persons must be treated as diseased persons and not as persons possessed of a devil. But if it be true, as I think is undoubtedly the case, that "the progress of the race, its intellectual and moral development" is a product of, or has arisen in the course of, organic evolution, the whole object and end of evolution has not been the development of ferocity. This conclusion is not wholly new. Huxley, years ago, remarked that man, having attained to his present state, would be glad to see the ape and the tiger die, but they refused to suit his convenience. But, new or old, the conclusion needs more emphasis than it has received in the last five years or more. Good animals are necessary, but good men are still more necessary if the race is to distinguish itself from other animals by properties other than mere anatomy. The Greeks recognized this; for Sophocles, in his chorus of Antigone, made this statement:

> Of all strong things none is more wonderfully strong than Man. He can cross the wintry sea, and year by year compels with his plough the unwearied strength of Earth, the oldest of the immortal gods. He seizes for his prey the aery birds and teeming fishes, and with his wit has tamed the mountain-ranging beasts, the longmaned horses and the tireless bull. Language is his, and wind-swift thought and city-founding mind; and he has learnt to shelter him from cold and piercing rain; and has devices to meet every ill, but Death alone. Even for desperate sickness he has a cure, and with his boundless skill he moves on, sometimes to evil, but then again to good.

The Greeks, however, were remarkably free from superstition, considering the age in which they lived. The "city founding mind" does not reach its fullest opportunities until it has cleared away superstition. For one in peril of his soul does not think freely or accurately on all matters which pertain to him. Some of the agents which man has used in clearing away superstition may now be mentioned.

The Place of Biology in the Life of a Nation

Century after century man has been struggling to break down convention and obtain opportunity for the expression of his individuality. Often he has been defeated in the struggle and the progress of the world has halted for a time, or a particular nation has fallen into stagnation. But each time, somewhere in the world, man, driven by the forces within him, has sooner or later broken through the particular system of convention which aroused his anger. Man's reaction against convention may be viewed as a biological reaction. Man has attempted

to provide an environment, social and political, which permits the expression of individuality and which is worthy of man. Science has had its part in the struggle, and on the whole, it has been a worthy part. A brief statement of the place of science in the life of a people may be given here.

In the long run, the material advancement of the world has rested upon mathematics and the physical sciences generally, and the freedom of human thought from superstition, upon the natural and biological sciences. Not a railway is constructed, nor a great building erected, nor an ocean liner launched without previous mathematical calculation. The fundamental importance of all branches of mathematics for all branches of engineering is so well known as to need no further comment.

It is not so generally recognized, however, that man's freedom from superstition has come about through the development of the natural and biological sciences. But mothers in civilized countries no longer cast their children into the fiery image of Moloch to appease the gods who sent the plague in their wrath. We kill the plague-bearing rats and drain the swamps where the disease-bearing mosquitoes breed. Yet superstition lingers in the popular mind as an evidence that the task of biology is still unfinished. But on one point, biology has a clear, definite and unequivocal statement to make, and that is, no ruler holds his throne by divine right. The wisdom of all the doctors can not convince us to the contrary. If it is seriously believed in any country that autocratic rulers have any special prerogatives denied by the gods to ordinary mortals, it is a reflection upon the state of biology in that country. Nor is the biologist inclined to regard with much favor the claim of a people or nation to divine guidance in a greater measure than is granted to their neighbors. Much bloodshed might have been avoided if it had been clearly recognized that all claims of this sort rest upon superstition and not upon any rational foundation. From past experience one might predict what the reaction of man would be to any attempt to interfere unreasonably with the exercise or expression of his individuality. We may, then, look a little more closely into the elements that aroused a man's anger at the outbreak of the war.

(*To be concluded*)

WILLIAM HENRY PERKIN

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AS every school child knows to-day, the illuminating gas we use in our homes is largely obtained from the dry distillation of coal; but many men and women even to-day are not aware that, in addition to illuminating gas, other products of far-reaching commercial importance are also obtained from this same coal.

Among these coal-tar stands out preeminently. Not so many years ago it was a waste and a nuisance. To-day it rivals the coal-gas in utility.

From this dirty black tar, by a series of distillations, we get benzene and toluene and naphthalene and anthracene—to mention but four important substances—which are the starting-point for countless products of the dye and synthetic drug variety.

Out of benzene, for example, we can get aniline, and from the latter, Perkin, in 1856, obtained the first artificial dyestuff ever produced.

Born in England, the dye industry was reared and developed in Germany; and Germany owes much of its greatness, and very much of its downfall, to it. For the dye industry proved a nucleus for many other related industries. Thus dyes gave rise to the manufacture of sulphuric and nitric acids and caustic soda; these in turn to artificial fertilizers, explosives, and chlorine; and the latter to poison gas with all its concomitants. The medicine in small doses and the poison in large; chlorine as an antiseptic and chlorine as a destroyer—give them but the wrong twist, and man's ingenuity becomes positively harmful.

Perkin was born in London in 1838. He was the youngest son of George Fowler Perkin, a builder and contractor, who had apparently decided his son's future before the latter had discarded his swaddling clothes. Perkin, Jr., was to be an architect.

But Perkin, Jr., had not yet decided for himself. Perhaps it was a street-car conductor one day, a prime minister the next, and an engine driver the third. And then again, watching his father's carpenters at work, he wished to become a mechanic

of some kind; and plans for buildings fired him with the ambition of becoming a painter.

In any case, in his thirteenth year he had an opportunity of watching some experiments on crystallization. It goes without saying that he forthwith decided to be a chemist.

Were it not that about this time Perkin entered the City of London School, and there came in contact with one of the science masters, Mr. Thomas Hall, this latest decision might have been as fleeting as his previous ones.

The City of London School, like all important educational institutions of the day, considered science as an imposter in the curriculum, so that whilst Latin received a considerable slice of the day's attention, poor little Chemistry could be squeezed in only in the interval set aside for lunch.

A few boys, and among them Perkin, were sufficiently interested to forego many of their lunches and watch "Tommy Hall" perform experiments.

Hall's infectious personality made young Perkins all-enthusiastic. He was going to be a chemist, and he was going to the Royal College of Science, of which, and of its renowned chemical professor, Hall had told him much.

Hall's earnest pleading finally overcame the father's opposition, and in his fifteenth year Perkin entered the College. "Mr. W. Crookes,"[1] the assistant, was the one immediately in charge.

The head professor was Hofmann, an imported product. So suggestive and illustrative were the great chemist's lectures that, in the second semester, Perkin begged and obtained permission to hear them once again.

In the laboratory Perkin was put through the routine in qualitative and quantitative chemistry, Bunsen's gas analysis methods serving as an appendix. This was followed by a research problem on anthracene, carried out under Hofmann's direction, which yielded negative results, but which paved the way for successful work later. His second problem on naphthylamine proved somewhat more successful, and was subsequently published in the *Chemical Journal*—the first of more than eighty papers to appear from his pen.

When but seventeen Perkin already had shown his mettle to such an extent that Hofmann appointed him to an assistantship. This otherwise flattering appointment had, however, the handicap that it left Perkin no time for research. To overcome this the enthusiastic boy fixed up a laboratory in his own

[1] The late Sir W. Crookes.

home, and there, in the evenings, and in vacation time, the lad tried explorations into unknown regions.

The celebrated experiment which was to give the seventeen-year-old lad immortality for all time was carried out in the little home laboratory in the Easter vacation of 1856. It arose from some comments by Hofmann on the desirability and the possibility of preparing the alkaloid, quinine, artificially.

Starting first with toluidine, and then, when toluidine gave unsatisfactory results, with aniline—both being products of coal tar—Perkin treated a salt of the latter with bichromate of potash and obtained a dirty black precipitate.

Dirty, slimy precipitates had been obtained before and had, as a rule, been discarded as objectionable by-products. Perkin's first instinct to throw the "rubbish" away was overcome by a second, which urged him to make a more careful examination. And this soon resulted in the isolation of the first dye ever produced from coal tar—the now well-known aniline purple or mauve.

A sample of the dye was sent to Messrs. Pullar, of Perth, with the request that it be tried on silk. "If your discovery does not make the goods too expensive, it is decidedly one of the most valuable that has come out for a long time . . ." was the answer. Trials on cotton were not so successful, mainly because suitable mordants were not known. This second result somewhat dampened the enthusiasm of our young friend.

Nevertheless, Perkin decided to patent the process, and, if possible, to improve the product, as well as to find improved means of application.

Full of hope and courage, the young lad had decided to stake his future on the success or failure of this enterprise. He was going to leave the Royal College of Science, and with the financial backing of his father—who seems to have had a sublime faith in his son's ability—he was going to build a factory where the dye could be produced in quantity.

Hofmann was shown the dye and was told of the resolution. The well-meaning professor, who seemed to have had more than a passing fondness for the lad, tried all he could to persuade Perkin against any such undertaking. And let it be added that in that day, to any man with any practical common sense, Perkin's venture seemed doomed from the start.

A site for the factory was obtained at Greenford Green, near Harrow, and the building commenced in June, 1857.

"At this time," wrote Perkin years later, "neither I nor my friends had seen the inside of a chemical works, and whatever knowledge I had was obtained from books. This, how-

ever, was not so serious a drawback as at first it might appear to be; as the kind of apparatus required and the character of the operations to be performed were so entirely different from any in use that there was but little to copy from."

The practical difficulties Perkin had to overcome were such that, in comparison, the actual discovery of the dye seems a small affair. Since most of the apparatus that was required could not be obtained, it had first to be devised, then tested, and finally applied.

Nor was this all. Raw materials necessary for the manufacture of the dye were as scarce as some rare elements are to-day. Aniline itself was little more than a curiosity, and one of the first problems was to devise methods of manufacturing it from benzene.

The country was searched high and low for benzene. Finally Messrs. Miller and Co., of Glasgow, were found to be able to supply Perkin with some quantity, but the price was $1.25 a gallon, and the quality so poor that it had to be redistilled.

Now the first step in the conversion of benzene to aniline was to form nitrobenzene, and this required nitric and sulphuric acids in addition to benzene. Here again the market did not offer a nitric acid strong enough for the purpose. This had first to be manufactured from Chili saltpeter and oil of vitroil (sulphuric acid), and special apparatus had to be devised.

Bechamp's discovery three years earlier, that nitrobenzene could be converted into aniline by the action of finely divided iron and acetic acid was now developed for industrial use, and here again special apparatus had to be devised.

To-day the most fundamental operations in every dye factory are nitration—the conversion, say, of benzene to nitrobenzene—and reduction—the conversion of nitrobenzene to aniline. The mode of procedure, the technique, the apparatus —all are based on the work of this eighteen-year-old lad. Only those who have attempted to repeat on an industrial scale what has been successfully carried out in the laboratory on a small scale, will appreciate the difficulties to be overcome, and the extraordinary ability that Perkin must have possessed to have overcome them. Think of a Baeyer who synthesized indigo in his university laboratory, and then think of the twenty years of continuous labor that was required before the *Badische Analin Fabrik,* with its hundreds of expert chemists and mechanics, was in a position to produce indigo in quantity. And it would have taken them and others much longer, but for the pioneer work of young Perkin.

Some have described Perkin's discovery as accidental. Per-

haps it was. But consider the way it was perfected and made available; consider with what extraordinary ability every related topic was handled; consider how every move was a new move, with no previous experience to guide him; and who but one endowed with the quality of genius could have overcome all this? Hertz discovered the key to wireless telegraphy, but Marconi brought it within reach of all of us; Baeyer first synthesized indigo, but the combined labors of chemists in the largest chemical factory in the world were necessary before artificial indigo began to compete with the natural product; Perkin both isolated the first artificial dyestuff and made it useful to man.

In less than six months aniline purple—"Tyrian purple" it was at first called—was being used for silk dyeing in a Mr. Keith's dye-house. The demand for it became so great that many other concerns in England, and particularly in France, began its manufacture. In France it was renamed "mauve," and "mauve" it has remained to this day.

Perkin's improvements continued uninterruptedly, and his financial success grew beyond all expectations. He found that the uneven color often obtained in dyeing on silk could be entirely remedied by dyeing in a soap bath. The use of tannin as one of the mordants made it applicable to cotton, and shades of various kinds and depths of any degree could be attained without any difficulty. A process for its use in calico printing was also worked out successfully.

When, three years later, Verguin discovered the important magenta—or, as it is sometimes called, fuchsine—and later still Hofmann, his rosaniline, various details in the manufacture of mauve and its application to silk, cotton and calico printing, were appropriated bodily.

Young Perkin had given tremendous impetus to research in pure and applied chemistry. In the preparation of dyes, substances which had, until then, been curiosities, had now become necessities, and methods for their preparation had to be devised. This led to incalculable research in organic chemistry. In fact, it is hardly too much to say that the basis for most of the development in organic chemistry since 1856 lies in Perkin's discovery of mauve.

Industry has not been the only beneficiary. It will be remembered that using the dye, methylene blue, as a staining agent, Koch discovered the bacilli of tuberculosis and cholera. And coal-tar dyes are to-day used in every histological and bacteriological laboratory.

So rapid had been the progress of the industry that in 1861,

Perkin, who, though only twenty-three, was already recognized as the leading English authority, was asked by the Chemical Society to lecture on coloring matters derived from coal-tar, and on this occasion the great Michael Faraday, who was present, warmly congratulated Perkin upon his fine lecture.

Such dimensions has the coal-tar industry assumed since then that in 1913, at one single factory, the Baeyer works, in Elberfeld, Germany, there were employed 8,000 workman and 330 university-trained chemists.

Says *Punch:*

> There's hardly a thing that a man can name
> Of use or beauty in life's small game
> But you can extract in alembic or jar
> From the "physical basis" of black coal-tar—
> Oil and ointment, and wax and wine,
> And the lovely colors called aniline;
> You can make anything from a salve to a star,
> If you only know how, from black coal-tar.

In his little laboratory at the factory the various attempts made in improving the methods of manufacture were not the only time-consuming factors. The chemical constitution of mauve and related dyes, as well as purely organic questions not in any way related to dyes, also engaged Perkin's attention, and he began to contribute what was to prove an uninterrupted stream of papers to the *Transactions* of the Chemical Society. In 1866 he was elected to a fellowship in the Royal Society.

The year 1868 is memorable in the annals of chemistry as dating the first artificial production of alizarin, the important coloring matter which until then had been obtained exclusively from the madder root. This great triumph was due to the labors of Graebe and Liebermann. But the triumph for the time being was purely a scientific one. The process as worked out by these two chemists was far too costly to compete with the method used in extracting the dye from the madder root.

The starting point to the artificial production of alizarin was anthracene, another important coal-tar product. It so happened that the first piece of research Perkin had ever been connected with was related to anthracene, a topic taken up on the recommendation of his teacher, Hofmann. Naturally, Graebe and Liebermann's synthesis aroused his interest. He wished to find some method of producing it at less cost.

In less than a year Perkin had solved the problem. A modification of the method dispensed with the use of bromine, which was very costly. A patent was taken out in June, 1869, at about

the same time that Perkin's process had been discovered quite independently by Graebe, Liebermann and Caro.

Just as in the case of mauve, the supply of raw materials and the mastery of technical details, involved much labor and ingenuity.

To begin with, a constant and generous supply of anthracene was necessary. But where was this to be had? The tar distillers had had no use for it, and had not troubled to separate it in the distillation of tar. Many, indeed, there were among them who did not even know of its existence.

With the help of his brother the various distillers in the country were visited and the method of isolating the anthracene from the tar distillate was shown them. The promise that all anthracene thus obtained would be bought and paid for generously assured the Perkins of a plentiful supply.

The purification of the anthracene so obtained, the details of the entire process of manufacturing alizarin and the types of apparatus to be employed, were all exhaustively investigated. By the end of 1869 one ton of the coloring matter in the form of a paste had been made. This was increased to 40 tons in 1870, and to 220 tons in 1871. Until 1873, when the Germans also began manufacturing it, the Greenwood Green works were the sole suppliers.

In 1874 Perkin sold his factory, and from henceforth devoted himself exclusively to pure research.

Perkin exemplifies the type, more common than is often supposed, though one entirely beyond the comprehension of the average business man, who loves the quiet pursuit of research beyond aught else. Perkin exploited his discovery solely with the view of providing himself with an income, modest in the extreme, but sufficient for his extremely simple wants. To explore unknown fields at leisure and to be freed from all money matters whilst doing so were his aims.

When Perkin left the Royal College of Science at seventeen he had this in mind. Financial insecurity may spur one on, but to give the very best that is in one requires freedom from such burdens.

What led him to give up the factory and to devote himself exclusively to pure science was sheer love of the subject. It is the type of love which, when associated with genius, has led to the world's greatest literary and artistic productions.

After 1874 Perkin moved to a new house in Sudbury, and continued to use the old one as the laboratory.

His research work from now on touched but lightly upon

the dye situation. Until 1881 it centered much around the action of acetic anhydride on a group of organic compounds known as aldehydes. The first important result that was here achieved was the synthesis of coumarin, an odorous substance found in the tonka bean. This was the first case of the production of a vegetable perfume from a coal tar product.

These researches culminated in the now classical "Perkin's Synthesis" of unsaturated fatty acids—a group reaction which is studied by every student in chemistry to-day.

In 1879 Perkin was the recipient of the Royal Medal of the Royal Society, the other awards of the year going to Clausius, for his investigation of the mechanical theory of heat, and Lecoq de Boisbourdron, for the discovery of the element gallium. The president addressed Perkin as follows:

> Mr. William Perkin has been, for more than twenty years, one of the most industrious and successful investigators of organic chemistry.
>
> Mr. Perkin is the originator of one of the most important branches of chemical industry, that of the manufacture of dyes from coal-tar derivatives.
>
> Forty-three years ago the production of a violet-blue color by the addition of chloride of lime to oil obtained from coal-tar was first noticed, and this having afterwards been ascertained to be due to the existence of the organic base known as aniline, the production of the coloration was for many years used as a very delicate test for that substance.
>
> The violet color in question, which was soon afterwards also produced by other oxidising agents, appeared, however, to be quite fugitive, and the possibility of fixing and obtaining in a state of purity the aniline product which gave rise to it, appears not to have occurred to chemists until Mr. Perkin successfully grappled with the subject in 1856, and produced the beautiful coloring matter known as aniline violet, or mauve, the production of which, on a large scale, by Mr. Perkin, laid the foundation of the coal-tar color industry.
>
> His more recent researches on anthracene derivatives, especially on artificial alizarine, the coloring matter identical with that obtained from madder, rank among the most important work, and some of them have greatly contributed to the successful manufacture of alizarine in this country.
>
> Among the very numerous researches of purely scientific interest which Mr. Perkin has published, a series on the hydrides of salicyl and their derivatives, may be specially referred to; but among the most prominent of his admirable investigations are those resulting in the synthesis of coumarin, the odoriferous principle of the tonquin bean and the sweet-scented woodstuff, and its homologues.
>
> The artificial production of glycocoll and of tartaric acid by Mr. Perkin conjointly with Mr. Duppa afford other admirable examples of synthetical research. . . .
>
> It is seldom that an investigator of organic chemistry has extended his researches over so wide a range as is the case with Mr. Perkin, and his work has always commanded the admiration of chemists for its accuracy and completeness, and for the originality of its conception.

In 1881, Perkin turned his attention in an entirely new direction, that of the relationship between the physical properties and the chemical constitution of substances. Gladstone, Brühl and others were already busy connecting such physical manifestations as refraction and dispersion with chemical constitution. Perkin now introduced a third physical property, first discovered by Faraday: the power substances possess of rotating the plane of polarization when placed in a magnetic field.

With this general topic Perkin was engaged to the year of his death. His work has thrown a flood of light upon the constitution of almost every type of organic compound, some, such as acetoacetic ester and benzene, being of extraordinary fascination to every chemist.

There are chemists—and H. E. Armstrong is among them—who regard this phase of Perkin's life work as his crowning achievement. If it has not received such general recognition as his earlier work, that is to be largely ascribed to a lack of knowledge of physics which prevailed among chemists until quite recently. However, even as far back as 1889 Perkin was presented with the Davy Medal of the Royal Society as a reward for his magnetic studies.

The year 1906 marked the fiftieth anniversary of the founding of the coal-tar industry, and the entire scientific world stirred itself to do honor to the founder. A meeting was held on July 26 of that year at the Royal Institution in London, over which Professor R. Meldola, the then president of the Chemical Society, presided, and those in attendance included some of the most distinguished representatives of science in the world.

The first part of the meeting consisted in the presentation of his portrait (painted by A. S. Cope, A.R.S.) to the guest of the evening. A bust of Perkin (executed by Mr. Pomeroy, A.R.A.), for the library of the Chemical Society, was next shown. In addition the chairman stated that a fund of several thousand pounds had been collected for the endowment of chemical research in the name of "Sir William Henry Perkin" (he had been knighted in the meantime).

Professor Emil Fischer, president of the German Chemical Society, presented to Perkin the Hofmann Medal, which was accompanied with this address:

> Die Deutsche Chemische Gesellschaft hat Herrn Dr. W. H. Perkin in London Für ausgezeichnete Leistungen auf dem Gebiete der Organischen Chemie, in besonderen für die Begründung der Teerfarben-Industrie, den Hofmann-Preis verliehen. Berlin, im Juli, 1906. Der Präsident: E. Fischer. Die Schriftführer: C. Schotten, W. Will.

Professor A. Haller, representing France, presented Perkin with the Lavoisier Medal, with this address:

> La Société Chimique de Paris, a l'occasion du Jubilée destinée à célébrer la cinquantième anniversaire de la première matière colorante dérivée de la houille, et comme témoignage de haute estime pour ses travaux, est heureuse d'offrir au Dr. William Henri Perkin, Inventeur de la Mauvéine (1865), sa Médaille de Lavoisier a l'effigie de celui qui fut l'un des premiers et des plus illustres applicateurs des Sciences Chimiques à l'industrie et à la prospérité publiques. Le Secrétaire-Général: A. Béhal. Le Président de la Société Chimique de Paris: Armand Gautier. Juillet, 1906.

Addresses were also delivered by Dr. Baekeland, representing the chemists of America; Professor Paul Friedländer, on behalf of the scientific and technical chemists of Austria; Professor P. Van Romburgh, Holland; Professor H. Rupe, Switzerland; Lord Kelvin, representing the Royal Society; and Professor Meldola, on behalf of the English Chemical Society.

A passage from the Chemical Society's report is worth quoting:

> . . . However highly your technical achievements be rated, those who have been intimately associated with you must feel that the example which you have set by your rectitude as well as by your modesty and sincerity of purpose is of chiefest value. That you should have been able, as a very young man, to overcome the extraordinary difficulties incident to the establishment of an entirely novel industry fifty years ago is a clear proof that you were possessed in an unusual degree of courage, independence of character, judgment, and resourcefulness; but even more striking is your return into the fold of scientific workers and the ardor with which you have devoted yourself to the prosecution of abstract physico-chemical inquiries of exceptional difficulty. In the account of your renowned master, Hofmann, you have stated that one of your great fears on entering into technical work was that it might prevent your continuing research work; that you should have felt such regret at such a period is sufficiently remarkable, and it must be a source of enduring satisfaction to you to know that your later scientific work deserves, in the opinion of many, to rank certainly no less than your earlier.

How much Perkin was appreciated in Germany, where the coal-tar industry had developed into such gigantic proportions, is shown by the delegation that came from that country. There were Professor Bernthsen, Dr. H. Caro and Dr. Ehrhardt, of the Badische Analin und Soda-Fabrik; Dr. Aug. Clemm, Herr R. Bablich, and Dr. E. Ullrich, Farbwerke, Meister, Lucius, and Brüning; Dr. Klingeman, Casella and Co., Professor Carl Duisberg and Dr. Nieme, Farbenfabriken, Elberfeld, and Professor Liebermann—in short, the cream of Germany's industrial chemical fraternity.

And there were messages from Professor Beilstein (Petrograd), Professor Ciamician (Bologna), Professor Canizzaro (Rome), Professor Jorgensen (Copenhagen), Professor Takayama (Tokyo), Professor Adolf Baeyer (Munich), Professor J. W. Brühl (Heidelberg), Professor G. Lunge (Zurich), and Professor Hugo Schiff (Florence)—an international band of illustrious scholars.

In the autumn following the jubilee celebrations in London, Sir William Perkin accepted an invitation from the American committee to visit its shores. Various gatherings were held in his honor in New York, Boston, Washington, etc.

In New York a dinner was tendered him at Delmonico's, with the veteran Professor Chandler, of Columbia, in the chair. Dr. W. H. Nichols presented him with the first impress of the Perkin Medal, since awarded annually to the American chemist who has most distinguished himself by his services to applied chemistry; and Dr. W. F. Hillebrand, then president of the American Chemical Society, presented the diploma of honorary membership of the society to the guest of the evening. Other speakers included President Ira Remsen of Johns Hopkins, Professor Nernst of Berlin, and Dr. W. H. Wiley, chief chemist of the Department of Agriculture, Washington.

Aside from his scientific achievements Perkin's life was extremely uneventful. To him science was his life, and he seems to have had no avocation. We find no romantic dash, no such many-sidedness, as characterized his great countryman, Ramsay, for example. With modesty carried to the extreme, only the privileged few knew anything of the man, and even Professor Meldola, an intimate friend of many years' standing, could give but few personal touches of the man in his otherwise excellent obituary address, delivered to the members of the Chemical Society. ". . . I thank God, to whom I owe everything, for all His goodness to me, and ascribe to Him all the praise and honor." This was Perkin's review of his life in 1906. A blameless Christian, a perfect gentleman, a fine type of the old conservative, he lived unobtrusively, worked quietly and intensively, worshiped God, and respected his neighbor. To us, living in days of turmoil and upheaval, such a personage already belongs to an age long past.

Perkin was twice married. His first wife was a daughter of the late Mr. John Lisset. Some years after her death he married a daughter of Mr. Herman Molwo. Mrs. Perkin, three sons, and four daughters, survive him.

His sons are all noted chemists. One of them, Arthur George, is a technical expert, and another, William Henry, is professor of chemistry at Oxford. This Oxford professor is without doubt the foremost organic chemist in England to-day. His work on polymethylenes, alkaloids, camphor, terpenes, etc., is of the highest order.

Like that other grand Englishman, Darwin, Perkin, the genius, begot Perkins of genius. Not always are the gods so kind to the children of geniuses.

To great ends and projects had thy life been given;
Right well and nobly has the goal been won;
For this, O Great Discoverer, thou hast striven;
Take, then, our thanks, for all that thou hast done.
(Nora Hastings,—dedicated to Perkin).

THE PSYCHOLOGICAL MOMENT

By Dr. HARRY D. KITSON
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ONE of the expressions most frequently heard in these days of catchwords and high-sounding phrases is the term, "psychological moment." The term is applied to the most widely varying circumstances, from such relatively inconsequential affairs as the feeding of the baby to such momentous events as the precipitation of a World War; it is applied with equal readiness to the moment when the astute evangelist feels it proper to urge his hearers to hit the sawdust trail, and to the time when the seducer feels he may without fear of rebuff press his victim to take the first drink. No kind of human affairs appears too sacred and no kind too frivolous to be exempt from the influence of the psychological moment. As further evidence of the aptness of the term to cover a multitude of situations we find it applied to affairs in which there is no psychical factor whatever, such as a rain so timed as to save a corn-crop, or to the eruption of a geyser. From these instances we see that the term is a very useful one, playing a large part in the speech and thought of the day. True, it smacks somewhat of esotericism, but such connotation is belied by the fact that the term is not employed exclusively by savants, but is employed with equal glibness by the man of the street and even by high-school students.

Despite the popularity of the term it is likely that those who hobnob with it would be at a loss if asked to define it and give its characteristics. This is not to be wondered at, for the events that occupy such a moment are essentially psychic; they can not be touched and handled but only *felt,* and feelings are hard to describe. Most people would probably describe the moment as a time when some important issue hangs in the balance; as a time just preceding events of great consequence, when anything which is done has a serious effect upon succeeding events. An introspective account might employ such terms as "delicacy of equilibrium" and "nice adjustment of motives." It is a time when receptive and active processes are in abeyance to such an extent that we can "hear a pin drop." Then something occurs to break the tenseness, a change in action or feeling ensues and the moment is over. It has been noted in literature by Shakespeare who calls it

a tide in the affairs of men,
Which taken at the flood, leads on to fortune.

Napoleon pointed out its importance in deciding the fate of battles:

> In all battles, a moment occurs when the bravest troops . . . feel inclined to run. That terror proceeds from a want of confidence in their own courage; and it only requires a slight opportunity, a pretense, to restore confidence to them. At Arcola I won the battle with twenty-five horsemen. I seized that moment of lassitude, gave every man a trumpet, and gained the day with this handful. You see that two armies are two bodies which meet and endeavor to frighten each other; a moment of panic occurs, and that moment must be turned to advantage. When a man has been present in many actions he distinguishes that moment without difficulty; it is as easy as casting up an addition.

But so important a factor in human affairs deserves more than such passing comment. A psychic phenomenon so fraught with possibilities for action and feeling challenges serious attention and scientific analysis if we are to attain skill in controlling it.

In making a scientific classification of the states of mind that are most often accompanied by the moment we should designate them as feelingful and volitional. Examples of the former are numerous in the drama when the audience sits spellbound through a tense scene until the climax comes, which is nothing but the psychological moment. Examples of the latter may be found when not feeling but decision and action mark the critical change. For the sake of concreteness, let us take a volitional situation in which the presence of the psychological moment is clearly to be discerned. One of the best examples is the sale, for here are found the accompaniments of the psychological moment in all their poignancy. Furthermore, the process of selling touches so intimately the experience of every one that a psychological analysis of it will have intrinsic interest apart from its value in illustrating the theoretical aspects of the psychological moment.

The psychology of the sale is a most fascinating subject and deserves more lengthy consideration than can be given here. We must content ourselves in this illustrative treatment with the statement that a sale psychologically considered is a series of progressive mental changes on the part of the buyer, leading to an act of will which culminates in satisfaction. This definition will serve for every deliberated sale, whether it involves the purchase of a stick of candy or of an automobile. The task of the salesman throughout is to develop certain states of mind on the part of the buyer, all leading to the final mental state. The act of will is our present concern. True, its adequate anal-

ysis requires a thorough study of the psychology of volition, which is beyond the scope of our present purpose, but we shall confine ourselves merely to one stage in its progress.

The first principle of voluntary action to be considered is that before such an action can occur there must be in the mind an idea or thought of the act. An idea of the end to be attained must inevitably precede the attainment of an end. For example, in such a simple act as drawing a straight line, the directness with which one reaches the end of the line depends upon the intentness with which one keeps in mind the idea of the end. It is the anticipation of the effects of an act that is the precursor of a voluntary act. Applying this principle to a sale we see that the idea of purchase must be present, hence the first task of the salesman is to inject it into the mind of the buyer. So important is this initial idea that we shall hereafter for rhetorical purposes personify It and speak of It in capitals, though the reader is warned that such practice is strictly frowned upon in orthodox psychological circles. We shall take this liberty, however, for in these days when the psychological aspects of business operations are only dimly recognized we should be pardoned if we state things with slightly bizarre effect, in our efforts to show their importance. But apart from such claims to anthropomorphism, the Idea is important enough on other grounds to deserve capitalization, for sometimes It is able to set off our actions almost automatically. Through a kind of action technically known as "dynamogenesis," It occasionally passes over into action immediately and many sales occur without the exertion of any effort on the part of a salesman. For example, the Idea, "baseball score" is strong enough in its own right to lead us without further locution of thought, to reach into our pocket for a coin and buy a paper. Such a purchase is so shorn of voluntary characteristics as not to furnish us with an illustration of the psychological moment. But not all sales are of this "hair-trigger" type, and most Ideas even though carefully implanted in the mind do not lead directly to purchase but require manipulation. Indeed such is the case with all our deliberative sales, and an analysis of the fortunes of the Idea will lead us to our goal, the psychological moment.

The word analysis is used advisedly, for it indicates the true condition of affairs, namely, that at time of a sale there is more than one Idea in mind; there are many ideas there, each one potential of initiating appropriate action, and if any single purchase is to be consummated the corresponding Idea must be strengthened and the other ideas, eliminated. Accordingly, we see that in psychological terms the problem in making a sale is to strengthen

the central Idea in the mind of the buyer. How this may be done is a tale full of dramatic situations. Take, for example, the sale of an automobile. The buyer enters the salesroom already inoculated with the Idea of purchase. But, alas, he comes with many other ideas in his mind at the same time. He has, for example, an idea as to how his bank account will be depleted if he purchases a car; on the other hand, he has an idea of the pleasures which attach to motoring. Again, in addition to the Idea of this particular Car he has ideas about several other cars—lower-case i and c this time—which he has examined or intends to examine. All these ideas and many others throng upon his mental field until if it were graphically represented it would resemble a full-moon containing a central circle, freckled with numerous circlets of different sizes representing the ideas with their different strengths. It will be seen that these ideas bear different relationships to the central idea, some being hostile, others sympathetic. Whether they hinder or help they must be reckoned with and must be manipulated to the glory of the Idea, which must be nourished and expanded to such a degree that its bulk will crowd out all the other ideas. This task of nourishment confronts every salesman; indeed, from the psychological standpoint the salesman is not a vender of automobiles but a manipulator of ideas. His task is to fan the flame of the Idea until it becomes to the buyer the consuming interest in life. Beside it, everything must shrink to nothingness—the about-to-be-ravaged bank-account, the heart-rending burden of upkeep, the mortgage on the house, last year's unpaid coal-bill—all must be forgotten in the overpowering compulsion of the Idea. And the Idea must remain the greatest thing in the world long enough for the purchaser to sign his check or sign the pay-as-you-use contract.

To a superficial view the task of the salesman might seem to be that of taking hold of these unwelcome ideas and thrusting them into outer darkness, but such a conception is erroneous and will lead to egregious error. If the mind of the buyer contains the idea of another car the proper procedure is not to dilate negatively upon that car in the effort to drive it out of his mind. Every word uttered about that car acts as food for the unwelcome idea and causes it to wax larger and larger. The practise of criticizing or condemning a rival commodity is being recognized as poor business ethics, but we may go still farther and say that to speak either in praise or blame of rival goods is poor psychology, for every word makes the undesired idea still more troublesome.

What are the methods, then, by which the undesirable ideas

may be forced out of the mind and the desired one enhanced? The answer is to force all attention upon It and when this happens, the strength of the undesired ideas automatically decreases. The psychological situation may become clearer when described in terms of brain energy. The brain, according to some psychologists, is organized into a number of ideational systems, one for each idea that exists in the mind. Any ideational system may be roused into action by the drainage into it of brain energy. Now the energy of the brain may be distributed in various amounts over different systems, the amount in each system depending upon the strength of the corresponding idea. In the case of our sale, if the main Idea is to grow in strength its brain-system must drain off from the other systems the brain energy resident within them until the energy of the brain is all drained off into the one system, which means the triumph of the Idea.

Reverting to our psychological description of the sale, we might pause at this stage and elaborate upon methods of strengthening the Idea, but that would require a digression from our main interest—the psychological moment. Suffice it to say the process consists in using concrete material with which to embellish the Idea. The salesman must dilate upon the specific virtues of the car, upon the power and smoothness of the engine, the luxurious ease of the springs, the elegance of the upholstery; then he must attach as allies to the Idea, the subsidiary ideas that lurk sympathetically in the background of the mind of the buyer, showing how the car may be used to transport oneself and family to sylvan spots, how it may assist one to radiate an air of prosperity, and the like. And with each increment added to the strength of the Idea there is a corresponding diminution in the strength of the undesirable ideas until finally they all dwindle away, and the Idea is left with undisputed sway.

But we have been moving too rapidly in our description, and have passed over the magic moment. It comes just before the Idea bursts forth into action, when there is only a vestige of a contradictory idea making a last valiant stand against annihilation. And what a desperately uncertain period it is, and how the soul of the salesman is wrung with anguish! Though outwardly calm, he is inwardly consumed with anxiety. Will the carefully nourished Idea be powerful enough to rout its last bold opponent or will some hostile idea by a sudden sally pierce its none too sound armor? He realizes also the extreme delicacy of the moment and prays heartily that no untoward stimulus may arise to disrupt the delicate balance of brain-

energy. He knows from bitter experience how small a thing may destroy his work. He has seen many an "otherwise perfectly good sale" lost because of an empty fountain-pen, a telephone call, a baby's cry, an accident in the street. Anything, however unrelated to the commodity, may spoil the sale. Any salesman can describe a score of such catastrophes which make him assert that the psychological moment is the most critical stage in the sale. And he does not overstate the fact. The experience of sales managers goes to show that the salesmen who fail are deficient most frequently in ability to get past the psychological moment. They make a good approach, arouse interest in the goods and create strong desire, but are unable to make a good closing. They err in two ways—in trying to force a decision too soon, before the Idea has had time to reach its maximum dimensions, or in delaying to press for a decision until after the Idea has ripened and decayed. In either case, their error lies in a failure to recognize the psychological moment.

How may one recognize the psychological moment and how may one cultivate a sensitiveness for its approach? Undoubtedly there are signs that accompany it, for successful salesmen sense it readily. Their awareness of it, however, is not a vividly self-conscious matter, for they can not tell how they recognize it. If pressed for a description of their method, they would probably say, by intuition, and this may serve as well as any other word. But the process of intuition may be further analyzed and is found to be a process of conscious apprehension through sense avenues which we all possess. Many of the things that warn of the approach of the moment in the sale are small involuntary movements on the part of the buyer, such as slight inclinations of the head and trunk, minute contractions and relaxations of bodily muscles. Even so slight a change as that in the size of the pupil of the eye may serve to indicate to the practised salesman that the portentous moment has arrived. Other more obvious signs may consist of verbal responses of the buyer, for the skilful salesman does not do all the talking in engineering a sale; instead he throws out frequent feelers in the form of questions, and by the warmth of the response, can judge how nearly a decision has been reached. A hundred cues such as these are present and are automatically used by the expert salesman in regulating his conduct when the moment arrives.

Upon recognizing the moment what steps may the salesman take to see that it is passed most auspiciously? Our psychological analysis just completed will suggest several steps that

may be taken to increase the chances of success. One measure of prime importance is to stage the sale so that there will be no disturbances while it is in progress; for we have seen that every disturbance, no matter how trivial, means the introduction of a new idea into the mind of the buyer and a dislodgment of the balance of brain energy. In view of such danger the salesman should carefully isolate his buyer and separate him from things and people. This is the great psychological advantage of using a hotel show-room.

Another prophylactic measure is to have conditions favorable for immediate consummation of the sale. There must be no awkward delay when the moment arrives. The contract should be ready and the writing utensils at hand. All should move as smoothly as a theatrical preformance. Indeed, a sale in many ways resembles a drama and should be rehearsed with equal propriety.

As a third way of meeting the moment the following plan may be recommended: Assume that the sale is made—that the purchaser has decided to buy; and this will be true if the salesman has judged the moment rightly. He might indicate that he knows the decision has been made by the wording of his next remark: Which color of upholstery do you prefer? or, Do you wish immediate delivery? Or sometimes, his remarks should be so put as to commend the decision which he knows has been made. Careful observation will show that many purchasers, after having made up their minds, really desire to be talked to for a while in order to hear their choice justified; so very often, such a line of talk is the best accompaniment to the psychological moment.

This brief attempt to characterize the psychological moment has shown that it is a common phenomenon of mental life; that whenever it occurs, it marks a time of great importance in human affairs; that it is a period of very delicate equilibrium to be met with great sagacity and cunning. By means of our homely illustration taken from the everyday business of selling, we have seen that in spite of the occult connotation of the term, the phenomenon is not a miracle to be controlled by a few gifted initiates possessing mysterious powers of divination, but that it is a natural occurrence resulting from a clash of ideas under important circumstances; that it exhibits itself in observable changes in human behavior, readily apparent to any one who will study them. To one who thus recognizes the presence of this interesting psychological phenomenon and seeks to understand it, is given a new conception of the significance of human behavior and a vision of far-reaching possibilities of influencing and controlling it.

THE SUN, HEALTH AND HELIOTHERAPY

By GUY HINSDALE, A,M., M.D.

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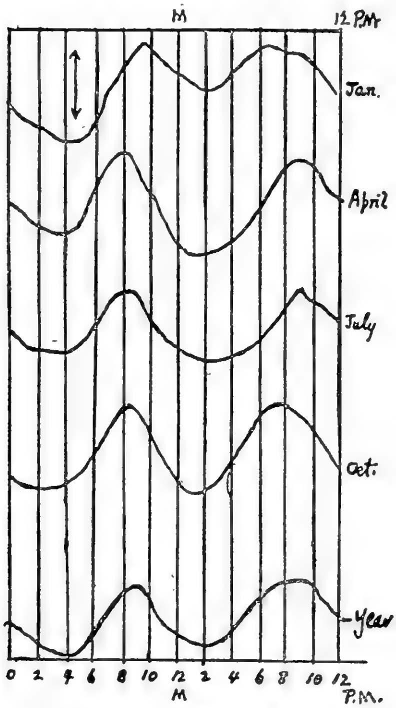
THE relation of the sun to human health and the vital functions is of such great importance that any phase of this subject is deserving of serious consideration. We are accustomed to accept, without question, the beneficent influence of solar light and heat, knowing as we do that actinic and chemical solar rays are necessary for the maintenance of animal and vegetable life upon our globe. These influences reveal themselves in greater or less degree according to the seasons and in the various zones into which we are accustomed to divide time and place in our planetary existence.

But meteorologists and astronomers and students of geophysics are constantly dealing with problems of more subtle type and have devised instruments, the very names of which are scarcely known beyond the physical laboratories and observatories now maintained for research in these hidden realms of the solar and terrestrial forces. Among them we may mention as preeminent in this field the Carnegie Institution of Washington, with its department of research in terrestrial magnetism; the geophysical and physico-chemical laboratories; and the solar observatories on Mount Wilson, in California, and at Calama, Chile, belonging to the Smithsonian Institution. We have also the United States Weather Bureau with its trained experts and well-equipped research laboratories and observing stations; and the Smithsonian Institution with its astrophysical observatory at Washington. The British Empire has its Royal Meteorological Society, with observatories at Kew, Greenwich and Stonyhurst; France, its Société Astronomique under the direction of the distinguished M. Flammarion and, in addition, the Bureau Central Météorologique.

Some have supposed that the sun's electric energy has an influence upon human health and vital functions at the earth's surface, so the author made inquiry of the directors of these institutions and laboratories which have been enumerated. It would appear, however, that the value generally assigned to this phase of the sun's energy at our distance from it, approximately 93,000,000 miles, is small.

In conversation with the late Professor Cleveland Abbe, of the Weather Bureau, he told the writer that we have very little knowledge of the sun as a source of electric energy except as it affects our magnets. It is an immense source of energy; but the gravitational or potential, thermal, optical, actinic and magnetic effects are the only ones that have as yet been measured. The electromagnetic influences of the sun and moon on the magnetic needle at the earth's surface have been observed for many years and a magnetic influence may also be attributed to the same forces that produce the sun spots. This is a manifestation of electric energy transformed into magnetism.



SUMMARY OF OBSERVATIONS AT THE KEW OBSERVATORY, ENGLAND. Dr. Chree. Diurnal Variation in Terrestrial Magnetism. The scale is indicated by the line showing the length equivalent to 50 volts. (Volts per meter.)

Whenever so-called magnetic storms are manifested either by the auroral light, or by disturbance on our telegraph wires or ocean cables, these are explicable in general as the transformation of waves of electric influence or energy, analogous to those that are used in our aerial or wireless telegraphy; but measurements of their intensity have as yet been confined to the Department of Terrestrial Magnetism.

On applying to the Bureau of Standards, Washington, Dr. S. W. Stratton, the director, said that there appears to be no doubt that the magnetic field at the earth's surface is affected by disturbances upon the sun; the electrical field in the earth's atmosphere is also affected, at least indirectly, by the radiation from the sun. Those effects are revealed by the observational study of terrestrial magnetism and of atmospheric electricity. As the action of any of these fields or of their changes upon health is independent of the source of the fields or of their changes, a simple problem would involve ignoring the source, whether the sun or something else, and seeking merely the relation between health and the magnitude and variation of these fields as observed on the earth.

According to George Mahomed, of Bournemouth, who has summarized the daily and monthly observations made by Dr. Chree, the director of the Kew Observatory, the fluctuations in days and months are very considerable. They show a diurnal variation. The maximum of potential occurs in the summer months at about 8 A.M., and between 8 and 10 P.M. In the winter the maximum is about 10 A.M. and the evening maximum at between 6 and 8 P.M. The readings are always higher in winter than in the summer. The morning minimum is about 4 A.M., throughout the year; the afternoon minimum is usually about 2 P.M. In the winter the weather conditions which accompany a high barometer favor the existence of high values and big diurnal changes in the potential. But in summer the barometric readings and the mean, the range, of daily variations of potential maximum seem to have no relation. A high potential occurs indifferently with a high or low barometer.[1]

It is admitted that the earth is negatively electrified and the atmosphere positively. This negative electrification of the earth is probably not uniform and we know that currents of greater or less intensity exist. The states of atmosphere vary considerably in the amounts of positive electricity they hold; but owing to the proximity of these differently electrified bodies there is a strain between them to establish an equipoise or, in other words, the tension may at times be broken by the earth giving up negative electricity and the atmosphere giving up positive electricity in order to form an equilibrium. The intensity with which this seeks to be established is called potential. The electroscope shows this by the behavior, the divergence, of the gold leaf. Mahomed illustrates very well this matter of potential by depicting a pointed, towering rock that tends to get rid of negative and attract thereby positive elecricity, when the potential in the neighborhood will be relatively high. Air currents condensed into a cloud in the higher strata would carry a positive charge; while those formed on the ground or the side of a mountain would probably carry a negative charge. If clouds of these two types should meet a sudden alteration of potential would result. The author has frequently witnessed such an interchange in the mountains of Virginia. In the western portion of the state there are numerous parallel ridges with deep and narrow intervening valleys. It occasionally happens that an electric discharge takes place from the summits of these ridges into the atmosphere. There is nothing audible, but merely a sudden glow of the higher clouds

[1] *Proceedings, Royal Society of Medicine,* December 8, 1909.

in the dark night, and it is possible that the presence of iron-bearing strata may have something to do with determining the electric tension thus manifested.

"Andes lightning" is the name given to a very striking luminous discharge of electricity seen over the crest of the Andes, in Chile, in a region where ordinary thunderstorms are almost unknown. The mountains appear to act as gigantic lightning rods, between which and the clouds silent discharges take place on a vast scale. Whether these phenomena have any solar connection, that is whether they are induced by previous exposure to solar radiation, we do not know. Such phenomena are observed elsewhere, but whether they may be related to vital functions or influence health in any way it is also difficult to say. We know, however, that the sun is positively electrified and the earth negatively and we would expect the potential to be highest near the surface of the latter. Mohamed has suggested that the heating of the earth's surface gives rise to a better ionization of adjacent portions of the atmosphere; it is a fact, probably, that no discharge of electricity takes place in the absence of electrons. These minutest particles of negative electricity have a velocity comparable to that of light. It is further known that the magnetic currents have a daily motion from west to east, that this motion is most marked in the tropics, while other currents go from the tropics to the poles; these latter through their property of deflecting the electrons into their course give rise to the *aurora borealis*. Sun spots, which are probably attended with high ionization hence give rise to disturbances of the magnetic fields of the earth's surface. It is probable that in these magnetic disturbances at the earth, very indirectly of solar origin, there may be some subtle influence on the human nervous system.

It was shown by Hale that there are magnetic fields in the sun spots. He was aided by the work of Zeeman, who discovered that powerful magnetic fields may split an ordinary single spectrum into several components.

All solar rays, whether visible or photographically active, or not, produce heat when absorbed upon a blackened surface. Sometimes the infrared rays are called heat rays, the light rays, visible rays; and the blue, violet and ultra-violet, "active" or "photographic rays"; but there is no distinction of kind between these things. All are regarded as transverse vibrations of the luminiferous ether, differing only in the wave length.

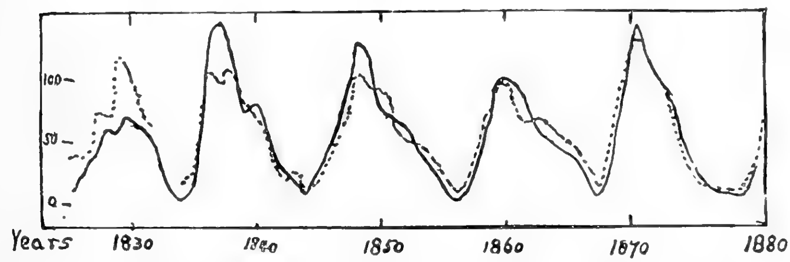
Waves of all wave-lengths produce their just effect when transformed into heat. Though both are forms of energy, radiation is not heat, but may be transformed completely into heat. We regard radiation as wave motion in the ether, heat as irregular motion of the molecules of material substances.

Sunlight has the power of ionizing the air, but there is a marked difference in the degree of ionization between that of the air at sea-level and at higher stations. Even in strong sunshine the surface air is only slightly ionized, but at the height of a few miles, as in balloon ascensions, the ionization may be twenty times as great as at the surface. Sunlight has also been

found to have the power of discharging the antennæ of wireless stations. It has also been found that rays received vertically have far more ionizing power than those received tangentially. Electric rays travel best by day in the narrow shell of dielectric between some stratum in the middle atmosphere and the surface of the earth.

It is a well-known fact that terrestrial auroras, northern lights and southern lights follow the sun spot periodicity and with this periodicity there is also a noteworthy change in the earth's magnetic field. This latter connection is very close as seen by the magnetic curves plotted by Dr. C. G. Abbot in his work on "The Sun."[2]

Abbot says that great sun spots often seem to be the direct



The Full Curve shows Sun Spot Relative Numbers. Dotted Curve, Diurnal Range Magnetic Declination. Data of Wolf and Young.

promoters of great magnetic disturbances and auroral displays, and that the earth's surface air temperature is, on the whole, lower at sun spot maximum than at sun spot minimum. It is only within the last ten years that we have had any direct measurement of solar radiation sufficiently accurate and complete to show these changes. Hale by his discovery of the existence of magnetic fields in sun spots has added to our knowledge of these very remarkable phenomena. Even the form in which matter exists in the sun has only lately been found to be gaseous. At least that is Abbot's and Schmidt's conclusion.

But are the sun spots, after all, potent for good or evil as far as we are concerned? Very few, aside from professional astronomers, have ever seen them, but nevertheless they appeal strongly to the popular imagination. There is undeniably much mystery about them. These fascinating phenomena are huge uplifts of metallic vapors in which vanadium, titanium and iron are evident, while at the top of these immense vortices there is an inflow of hydrogen and vapor of calcium. As they

[2] Page 187.

expand, lose heat and absorb solar light, they appear dark by contrast; so that, instead of 6,000 degrees Cent., which is the estimated temperature of the sun's surface, their temperature drops to approximately 3,500 degrees Cent. The magnetic field which has been detected in sun spots is believed to be due to the friction of the various vapors and gases and chemical compounds in the stupendous whirling motion that characterizes them.

Among those who have lately thrown light on this question is Dr. A. L. Cortie, the distinguished astro-physicist of Stonyhurst College Observatory. He does not believe that there is any basis for the impression that these spots in their immensity act directly to cause magnetic storms on the earth, although it is admitted that these do accompany the appearance of large active spots on the sun. His explanation is of great interest and may be correct. He says:

> The fields are much too weak, at the enormous distance of the sun, to allow of any such direct action. But great solar outbursts must be accompanied by a copious outflow into surrounding space of electrified particles called electrons. The earth is a great magnet, and its lines of force cut the surrounding atmosphere, which, as the barometer shows, has a diurnal oscillation. Hence we have matter moving across lines of force. If one takes a magnet and thrusts it into a coil of wire which is connected to a delicate galvanometer which can show the existence of electric currents, the needle will be deflected, indicating the flow of an induced electromagnetic momentary current. But it is obvious that the wire must be a conductor. A non-conducting material would not have an induced current produced in it. Substitute for the magnet and its lines of force the earth and its lines of force, moving relatively to the atmosphere. Evidently if the atmosphere, which is ordinarily a non-conductor, can be made a conductor electromagnetic currents will be produced in it. Now, when the copious streams of electrons from a disturbed area strike the upper atmosphere of the earth it does become a conductor, or, as it is termed, is ionized. Hence electromagnetic currents are set up, as indicated by the aurora borealis; the earth currents are induced, which upset by their fields the normal magnetic field of the earth, and our instruments record magnetic storms. The source of the energy, therefore, which causes magnetic storms is the rotation of the earth; the electrification of the upper atmosphere simply pulls the trigger and enables the forces to be operative.[3]

All this has a very important commercial and military bearing when we consider that the sun itself can take a hand in the conduct of a great war. Not that the sun should stand still as in the days of Joshua in the battle of Ajalon, but that it should tie up the great wireless plants on which modern warfare relies for daily aid.

With the cutting of the German-owned Atlantic cable at the

[3] *Current Opinion*, November, 1917.

beginning of the war, Germany had to fall back upon her wireless plants in order to transmit news and official or diplomatic messages through a channel not controlled by her enemies. For this the Sayville station on Long Island for a time became the distributing center, the wireless messages being thence transmitted by neutral cable or telegraph to all parts of the world. But when the aurora borealis appeared in May, 1915, the service was suddenly severely handicapped and for several weeks the messages received were for the most part fragmentary or often impossible to decipher. The same situation existed in Tuckerton, New Jersey, much to the dismay of the German owners.

We think it a very significant fact that electric waves, as, for example, those used in the wireless telegraphy, travel with the velocity of light, or at the rate of 186,330 miles per second and it suggests a very close relationship,—more than a mere analogy,—between light and what we designate as electricity. Radiant energy, therefore, proceeding from the sun may be held to include light, heat and electricity and it might be unjustifiable to differentiate too closely between them as we have been wont to do in the past. As we have intimated, our knowledge of some of these attributes of the sun is of very recent date.

As Dr. Abbot, the director of the Astrophysical Observatory of the Smithsonian Institution, says in his work, which we have freely quoted:

> That which the sun sends to the earth in such abundance used to be considered as three distinct things, namely,—actinic or chemical rays; light, or visible rays; heat, or invisible rays. These distinctions are known to be misleading. . . . All rays may be totally transformed to produce heat, however they may differ in their effects upon the eye, or in different chemical substances. All these rays travel with equal velocity in free space.

We are thus compelled to take a very broad view of solar radiation and to give to the electric energy of the sun a wider scope than at first thought would seem appropriate. Thus it is that heliotherapy, the principles of which we shall outline, may owe some measure of its efficacy to the electric energy of the sun. We are very far yet from a complete understanding of X-rays, the Finsen light, heliotherapy and other forms of radiant energy, not to speak of Marconi waves as applied to man's needs in other fields.

We all know that the disturbances of the mental and nervous equipoise are often traceable not only to social environment, but to climatic conditions and, in the belief of the ancients, and

even of some of the present day, to lunar influences. That solar irradiation has a considerable influence is undoubtedly true. It is constant; clouds may intervene, but cannot wholly check its power.

There is at the present time a remarkable interest in what is known as heliotherapy. This branch of physical therapy is winning an established place in the treatment of tuberculosis both of the bones and joints and of the pulmonary organs. During the last ten years heliotherapy has been systematically applied in these affections at suitable stations in the Swiss Alps, and on the French Coast, both on the Mediterranean and Atlantic shores and in Alton, in Hampshire, England. It has also been carried out to some extent in America, but not with the thorough and painstaking methods adopted in Europe.

One of the most ardent exponents of heliotherapy is Dr. A. Rollier who, during the last sixteen years, has treated upwards of 1,500 patients, both children and adults, by gradual exposure to solar irradiation at his institutions in Leysin, near St. Moritz, Switzerland.

At the French marine stations, notably Berck-Plage, Hyères and Cannes, the same method of treatment is adopted and the same good results obtained. The proportion of cures in advanced and apparently hopeless cases of surgical tuberculosis seems incredible. Rollier's clinical records, fortified with photographs taken on admission and discharge, fully corroborate his reports and dispel what might be a pardonable incredulity.

The author has recently brought to the attention of American physicians this remarkable development of tuberculotherapy and begs to refer to his essay on "The Atmospheric Air and Tuberculosis," Smithsonian Institution, Washington, 1914.

Rollier has succeeded in training his patients, both children and adults, by systematic and strict methods adapted always to the individual case so that they live in the free air of the Alps almost wholly naked, but apparently in perfect comfort; the training begins with exposure to the air and, afterwards, exposure to the sunlight, solar radiation, constituting heliotherapy. Under no circumstances does Rollier allow the patient to be exposed to the sun on the same day or even on the day following his arrival in the mountains. According to the gravity of the case or the general resistance of the patient, from three to ten days are allowed for acclimatization to the altitude and training for the air cure. Children seem to display an especial tolerance for exposure to sunshine.

There is one remarkable feature of the higher Alpine re-

sorts such as Leysin, Davos and St. Moritz, and that is that there is a vast difference between the temperature of the air in the sunshine and in the shade. Although snow may be lying on the ground, temperatures of 95 to 100 degrees Fahr. or even higher in the sun are not uncommon.

Sunlight has considerably more actinic force at these mountain stations than at the seashore, and hence the time required for the deep pigmentation essential to the solar cure is probably less than elsewhere. But even Rollier and others in the Swiss Alps have strongly urged the adoption of heliotherapy at the seashore sanatoria, and this is now quite as successfully accomplished. Rollier's record of over 1,500 patients and over 1,200 cures is one of the greatest contributions to modern surgical progress and especially to the fight against tuberculosis.

Heliotherapy in America.—In this country there is every opportunity for practising heliotherapy for tuberculosis and in the wider field which includes many chronic medical and surgical conditions not necessarily tubercular. There are now in military hospitals many cases of tuberculous disease of the bones and joints; and in addition, there are the inevitable torpid wounds, fistulas, and the gangrene, frost bite, and trench foot and the effects of caustic gases lately a part of military practise. Many of the sufferers are sent to Vichy and Aix-les-Bains for the baths; others are sent to Berck-Plage and to Cannes and other marine stations for the additional help of heliotherapy.

Dr. Albert Robin, in his work on tuberculosis, cites the well-known facts that the luminosity of the sea air and the power of the solar radiation at the seaside are very intense. The refraction of light by the sea water gives special properties with luminosity. The sea water absorbs the ultra-red rays that are calorific; it reflects the yellows (luminous) and the blue and violet rays that are chemical rays, the bactericidal action of which is recognized. Light is one of the best health-giving agents; it stimulates all the acts of animal life, particularly oxidation.

The luminosity of the sea air helps, then, to give it a more stimulating action than does the air of inland regions.[4]

Dr. Robin believes that the sodium chloride, iodine and silica (which he showed to be present at Berck-Plage) must exist in sea air in a state of ionization, or perhaps in a physical form which develops their radioactive properties. They in-

[4] Albert Robin, "Treatment of Tuberculosis" (English translation), J. & A. Churchill, London, 1913, p. 380.

crease the phenomena of oxide reducing hydrolysis which occupy the first rank in the acts of disassimilation in organic life. This makes us suspect, if not state precisely, the important part that must be taken by the chemical elements contained in sea air. All of them stimulate the exchanges, this in itself being one of the conditions of remineralization.

The author would strongly urge the establishment in the Rocky Mountain region, preferably in southern California, Colorado or New Mexico, perhaps in connection with some existing institution, of a true sun cure for tuberculosis. Such a locality is eminently suitable for heliotherapy, now for years most successfully carried out in the Swiss Alps by Rollier, and it should not be forgotten that his methods with their brilliant results are applicable not only in the class of cases commonly termed "surgical" tuberculosis, *i. e.*, bone and joint tuberculosis, but in pulmonary disease as well.

The time has come to give this method a thorough trial in the elevated, sunny and dry air of the Rocky Mountain region and Southern California, the climatic features of which justly hold first place in the climato-therapy of tuberculosis. Among the places in America where heliotherapy has been attempted there is a great difference in the amount and quality of sunshine, the *sine qua non* of successful treatment. Nevertheless it has been carried out in such variable climates as at Sea Breeze Hospital on Long Island, in Narragansett Bay, at Perrysburg (forty miles from Buffalo), and at the Children's Seashore House, Atlantic City. But it is in Colorado, New Mexico and southern California where the hours of sunshine are most uniform and least liable to interrupt the cure. Physicians in these states have already reported most encouraging results.

THE NORTHERN FUR-SEAL PROBLEM AS A TYPE OF MANY PROBLEMS OF MARINE ZOOLOGY

By Dr. BARTON WARREN EVERMANN,

DIRECTOR, MUSEUM, CALIFORNIA ACADEMY OF SCIENCES

THERE are in the North Pacific three closely related species of fur seals. One of these, known as the Japanese fur seal (*Callorhinus kurilensis*), has its rookeries chiefly on Robben Reef, in the Okhotsk Sea, with still smaller rookeries on one or more of the Kuril Islands. These constitute the Japanese fur-seal herd, which is the smallest of any. It is said this herd in 1911, contained but 6,557 seals. The second species has its breeding grounds on Bering and Copper Islands of the Commander Group off the coast of Kamchatka. This species (*Callorhinus ursinus*), constitutes the Russian fur-seal herd which, in1911 contained between 18,000 and 30,000 seals. The third species is the Alaska fur seal (*Callorhinus alascensis*), whose breeding grounds are on the islands of St. George and St. Paul of the Pribilof Group in Bering Sea, about 200 miles from the nearest point on the mainland of Alaska. This species constitutes the Alaska or American fur-seal herd which, according to the census of 1911, contained 127,745 seals. The Alaska fur-seal herd is not only much larger than both of the other herds combined, but the fur is regarded as superior.

Russian Control of the Alaska Fur-seal Islands

The Pribilof Islands, the only land on which the Alaska fur seals ever haul out for any purpose, were discovered in 1786, by Gehrman Pribilof, who for three years or more had been exploring Bering Sea in the interest of a Russian fur company. He at once took possession of the islands in the name of Russia. For the next thirteen years the islands were exploited by various rival companies. There was no thought of conservation, with the result that the herd was almost destroyed by 1798. In 1799, the Pribilof Islands, together with all the rest of Alaska, passed into the hands of the Russian-American Company. This company carried on the sealing business with autocratic power and with slight appreciation of the necessity of avoiding methods calculated to bring about the extinction of the herd, until in 1867, when Alaska was purchased from Russia by

IN AUGUST AND SEPTEMBER THE PUPS ARE OFTEN SEEN IN THE WATER ABOUT THE SEAL ISLANDS, LEARNING TO SWIM, thus preparing for the life in the ocean which they will lead for the greater part of their lives. This is a scene off Polovina Cliffs in August, 1916. Photo by Hanna.

the United States. In the season of 1868, the first of American occupation, two rival companies killed seals on the islands in the most reckless manner. The Congress then made the seal islands a government reservation and during the season of 1869, the killing was conducted under the direction of the Treasury Department. Then the islands were leased for a term of twenty years beginning in 1870, to the Alaska Commercial Company. This company was given the exclusive privilege, under the direction of the Treasury Department, of killing seals on the islands. The essential features of this lease were: (1) No female seals to be killed, (2) no male seals under one year old to be killed, (3) the killings after August to be limited to supplying food to the natives, (4) the total number to be killed in any one year not to exceed 100,000.

Upon the expiration of this lease the islands were again leased on March 12, 1890, but to a new concern, the North American Commercial Company. The lease was again for a period of twenty years and differed from the old lease chiefly in that no quota was fixed, except for the year 1890, when it was not to exceed 60,000, and the revenue derived by the government was \$10.22½ per skin as against \$3.17½ under the first lease.

Under these leases the companies were permitted to kill seals only on the land; they were not permitted to kill seals in the ocean.

Killing Seals on the Land

The number of seals in the American herd when it came into the possession of the United States was very great; in 1873 it was estimated at 4,700,000. This number is undoubtedly very much too great; probably half that number would be a very liberal estimate. At any rate, it is quite certain that an annual kill of 100,000 young male seals could then be made without in the least endangering the herd.

So long as the killing was confined to the land it was easy so to regulate the killing as to permit an annual take of 100,000 young males and yet maintain the herd at a high degree of productivity; in other words, the annual kill of 100,000 young male seals would be made good by a net increase of at least 100,000 young males reaching the killing age each year.

Habits of the Fur Seal

The fur seal is highly polygamous, living in the ocean the greater part of its life, and coming out upon the land only during the breeding season, which is in the summer from June

until in the fall. The breeding males are called *bulls;* the breeding females are called *cows;* the young are called *pups;* young, non-breeding males (from one to five or six years old) are called *holluschickie*, or *bachelors*. As the breeding season approaches the breeding seals begin landing upon the islands. With them come the bachelors, especially those more than one year old. The old bulls haul out first, each taking up a favorable position on shore and capturing as they land and holding in his harem as many cows as he can control. The number of cows in a harem may range from one to one hundred, the number varying with the abundance of bulls. The harem of average size under proper regulations will contain perhaps twenty-five to forty cows. Besides the breeding bulls there will usually be a varying number of half bulls, surplus bulls or waiting bulls, ready to become harem masters whenever opportunity offers. The number of surplus bulls will be few if the annual killings for the past few years have been excessive, or they will be many if the annual killings have not been large enough. Careful regulation of the killings is therefore essential to keep the number of surplus bulls within safe limits.

During the breeding season, the old males remain constantly on shore, never leaving the land until late in the fall. The cows, after their pups have been born, make frequent trips out in the ocean, often going 100 to 250 miles from the islands, to their feeding grounds. The younger bachelors also return to the water from time to time.

It is thought that the majority of young seals under two years of age, both males and females, remain in the water until in the fall, and come out on the land in force only when two years of age or older.

In the fall of the year, after the breeding season is over and the pups have learned to swim, the entire herd leaves the land and takes to the sea. In the winter they go as far south as off the southern California coast. Their migration route has been only roughly determined. In the spring they return to the islands. During this return they appear in numbers off the coasts of Washington and British Columbia, in the Gulf of Alaska and in the passes among the Aleutian Islands. During this return migration the cows are heavy with young and spend much time sleeping on the surface of the water. Each cow produces a single pup, which is born within a few days after she reaches the islands. She is served by the bull within a few days after her pup is born; the period of gestation is therefore only a few days short of one full year.

Pelagic Sealing

As already stated, so long as seals were killed only on the land it was possible to regulate the killing in such a way as to maintain the herd at its maximum size and productivity. The essential regulations would be: (1) Kill no females; save them all for breeding purposes. (2) Of the natural annual increment of commercially desirable young males (say those from three to five years of age), kill all except such number as may be needed to provide the necessary number of bulls each succeeding year. This number can be determined very exactly through carefully conducted scientific investigation.

During the forty years of leasing the killing on the land, although carried on without any intelligent understanding of the principles involved and in almost total ignorance of a number of the most important facts in the life history of the fur seal, was, in the main, conservative and not seriously detrimental to the herd. But in the last years of the lease of the Alaska Commercial Company, in the late eighty's, a new factor was introduced. Certain persons, chiefly Canadians of Victoria, British Columbia, discovered that the hunting of seals in the ocean could be carried on with profit. They found that, by falling in with the seal herd in the late winter and early spring off the coast of Washington, British Columbia and southeast Alaska, during the spring migration back to the Pribilof Islands, and again with the mother seals in Bering Sea in summer and fall when they visit their feeding grounds, large numbers of seals could be killed and the business of pelagic sealing, as it was called, made very profitable.

Following this discovery, the growth of the pelagic sealing industry was very rapid and the herd diminished correspondingly.

On the land, the killing can be, and was, selective; only surplus or unnecessary males were killed. No such selection is possible in pelagic sealing, even if the hunter were disposed to select, which he never was. When the hunter sees a seal in the water he can not tell whether it is a female or a male, so he tries to get every seal he sees. Of those he kills or mortally wounds, he probably does not recover more than one in five; some put the ratio at one in ten. On the basis of five to one, the number of seals killed outright or whose death was caused by the pelagic sealers from 1890 to 1897, has been computed to have been 1,907,217 males, 3,814,434 females, or a total of 5,721,651 seals. The total number killed on land during the same period on the Japanese, Russian and Pribilof Islands was: females, none; males, 350,268; from which it is easy to understand the cause

of the rapid decrease of the fur-seal herd during the last decades of the nineteenth century.

THE MODUS VIVENDI OF 1891 TO 1893

The disastrous results of pelagic sealing had become so evident that the governments of the United States and Great Britain agreed upon a modus vivendi on June 15, 1891.

The essential terms of this modus vivendi were that it closed the eastern part of Bering Sea to pelagic sealing so far as the subjects of the United States and Great Britain were concerned and limited the killings on our islands to 7,500 annually—the number required by the natives for food. The agreement was put into effect too late to do any good in 1891, even if it were

SLEEPING BACHELOR SEAL.
Tolstoi Rookery, St. Paul Island, July 21, 1892. Photo by Evermann.

possible for it to have done so; the pelagic fleet had already entered Bering Sea and begun killing seals, and when warned out of the protected area, they crossed over to the western part and continued their killing, which proved so profitable that the number of boats actually increased next year.

The agreement, originally made for one year, was extended to cover the seasons of 1892 and 1893.

TREATY OF FEBRUARY 29, 1892

As contemplated by the modus vivendi, a treaty was entered into between the United States and Great Britain February 29,

1892, the essential provisions of which were: (1) The appointment of a commission to make investigations concerning the habits of the fur seal, pelagic sealing, and the management of the herd on the islands, and (2) the reference of all matters in dispute to a tribunal of arbitration.

The Paris Tribunal

This tribunal, consisting of seven arbitrators, met in Paris in February, 1893, and concluded its labors on August 15, following.

The American contention, as presented to the tribunal, was, in brief, that the decline in the herd was due solely to pelagic sealing; that pelagic sealing was indiscriminate, the kill consisting chiefly of females heavy with young or of mother seals with nursing young on the islands. The British contention was that the proportion of females in the pelagic catch was inconsiderable and that excessive killing on the land was the sole cause of the decline in the herd.

It is interesting to note that of the five questions in dispute submitted to the Paris Tribunal four were decided against the United States, and the remaining one was of no importance!

The tribunal then drew up a set of regulations, in nine articles, which the two governments agreed to observe. The only one of these regulations that is of primary importance is the first, which prohibited the subjects of Great Britain and the United States from killing seals in Bering Sea within a zone of sixty miles radius around the Pribilof Islands; and this, as well as all the other regulations established by the tribunal, was utterly useless in protecting the fur seal.

As previously stated in this paper, the cow seals during the breeding season go 100 to 250 miles from the Pribilof Islands to find suitable feeding grounds; indeed, practically all their feeding grounds are now known to lie well outside the sixty-mile zone.

The result was that pelagic sealing went merrily on so far as Canada was concerned, but the United States on December 29, 1897, passed a law making it unlawful for any of its citizens to engage in pelagic sealing at any time or in any waters, thus putting squarely upon the British and such other nations as might engage in pelagic sealing the entire responsibility for such results as might follow from killing seals in the open sea.

Failure of the Paris Regulations

The Paris regulations proved therefore almost utterly useless in protecting the fur seal. In the first place, only the United States and Great Britain were bound by the regulations. Other nations that were interested and wanted to be parties to

the treaty, for example Japan, but which were refused, were not bound by the regulations. They had a perfect right to kill seals anywhere on the high seas outside the three-mile limit, and Japan was quick to exercise that right. That country entered the field at once. Not being a party to the treaty of 1892, Japan was not bound by the Paris Tribunal regulations.

A MOTHER FUR SEAL AND HER PUP.

She could lawfully kill seals anywhere on the high seas, right up to the three-mile limit around the seal islands.

They did so, and found the business quite profitable. So destructive was pelagic sealing under the Paris Tribunal regulations that the herd, by 1911, had been reduced to a mere remnant of 127,745 seals all told, in spite of the fact that killing on the land fell from 30,654 in 1896 to 12,006 in 1911.

United States Abandons Leasing System

At the close of the period for which the islands had been leased to the North American Commercial Company for sealing

purposes, the United States decided to discontinue the leasing system. This action was taken by Congress April 21, 1910, upon the recommendation of Hon. Charles Nagel, then Secretary of Commerce, and Hon. Geo. M. Bowers, Commissioner of Fisheries. It provided that all sealing should hereafter be done by the government and the skins taken to be sold by the government to the best advantage. Beginning, therefore, with the season of 1910, the sealing on the Pribilof Islands has been carried on directly by the government.

Treaty of December 15, 1911

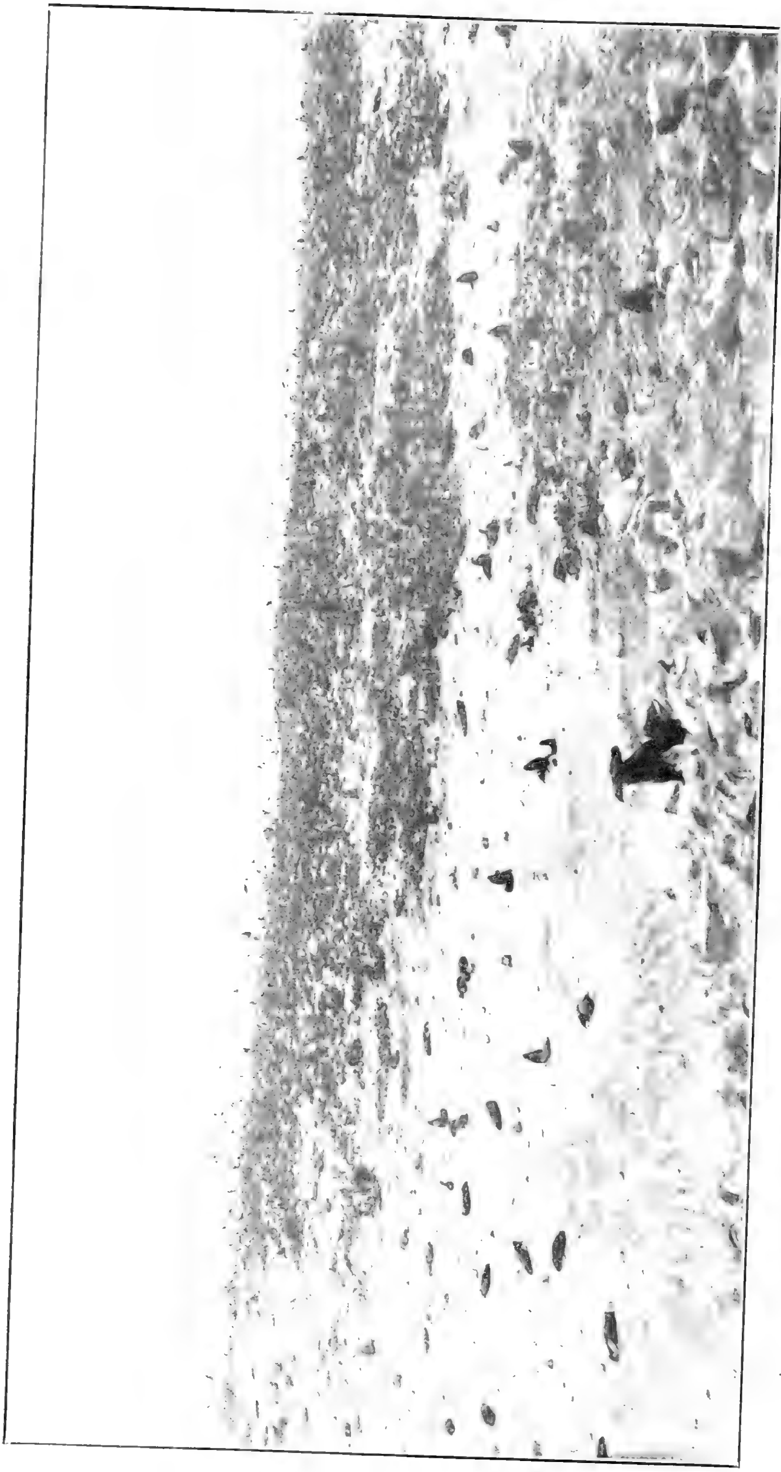
In the summer of 1911, a convention was signed by the United States, Great Britain, Russia and Japan. By the terms of this treaty, which became effective December 15, 1911, each of the four governments signatory thereto, agred to prohibit its citizens from engaging in pelagic sealing. This provision also applies to the killing of sea otters. Great Britain and Japan thus gave up their right to kill seals and sea otters in the sea beyond the three-mile zone, a right which they undoubtedly possessed. In return for giving up this right, Great Britain and Japan are each to receive 15 per cent. of all the skins that may be taken on the land by the United States on the Pribilof Islands, and like percentage of those taken by Russia on her seal islands. In like manner Japan gives to the United States, Great Britain and Russia each 10 per cent. of the land catch from the small but growing herd under her jurisdiction.

Close Season of Land Killing

On August 24, 1912, Congress passed a law giving effect to the treaty of 1911, and, unfortunately, including at the same time a clause prohibiting all killing on the land for a period of five years. There was, therefore, no commercial killing of fur seals on our islands in 1913 to 1917, both inclusive. The terms of the treaty relating to pelagic sealing are, apparently, being observed and carried out in good faith, and the Alaska herd has increased from 127,000 seals in 1911 to 530,492 in 1918, when land killing was again resumed. This increase in the herd is most gratifying and shows clearly that the herd recovered rapidly upon the cessation of pelagic sealing.

Government Handling of the Fur-seal Problem

In the main, the government has handled the fur-seal question fairly well. The administration of the laws and regulations by the Treasury Department, the Department of Commerce and Labor, and the Department of Commerce through the Bureau of Fisheries and its agents on the islands, was faith-



A TYPICAL FUR SEAL ROOKERY. Note the large bulls scattered over the rookery and the surplus or waiting bulls in the foreground.

fully and intelligently conducted, at least up to the enactment of the close season law. However, several very serious mistakes have been made and it is to some of these that I now wish to call attention.

The most serious mistakes which the government has made have been: (1) Failure to realize that the fur-seal problem is, primarily, a biological problem; (2) disinclination to listen to the advise and council of scientific men; (3) failure to realize that preservation of the fur-seal herds requires the cooperation of several different countries.

Congress and the heads of the executive departments concerned seem wholly unable to realize that proper laws and regulations for the management and conservation of the fur-seal herd must be based upon accurate knowledge of the life history of the fur seal. Up to the time of the modus vivendi no study had ever been made of the life history of the fur-seal by any trained naturalist. It is true that many valuable observations were made in 1873–74, but they were in the main inconclusive; they were wholly so as to practically every fact of vital importance.

How to tell the age of seals in the different categories, the age at which the males and the females begin to breed, the period of virility of each, the age to which each lives, the proper size of the harem, to what extent the yearling males and females appear on the land, the migration routes, feeding habits and grounds, natural mortality, principal enemies;—these are but a few of the many questions which could not be definitely answered, because the facts were not known.

In drawing up the terms of the modus vivendi, the United States, because of its lack of knowledge on these essential matters, agreed to terms which afterward proved very embarrassing, and very detrimental to the herd. The British said: "We will stop killing seals in the eastern part of Bering Sea if you will stop killing on the land." And the United States stupidly agreed; with the result that, while the number killed on the land in those three years was 27,040, the number killed at sea was 238,349. Stopping commercial killing on the land simply left that many more for the pelagic sealers to get.

The modus vivendi was, therefore, a total failure as a protective measure, chiefly so because, through lack of accurate knowledge of the feeding habits of the fur seal, we agreed to terms that proved disastrous.

The same was true with the Treaty of 1892, the Paris Tribunal, and the Paris Tribunal Regulations. Many things were agreed to that were biological mistakes, because of our

BREEDING BULL SEALS ON STARAYA ARTEL ROOKERY.
St. George Island, July, 1916. Photo by Hanna.

lack of complete knowledge. True, our commissioners made certain proper statements before the Paris Tribunal, but when they were disputed by the British, we were unable to support our contentions with convincing evidence. We lacked full accurate data to support our claims.

Naturalists many years ago began advising the government to provide for careful scientific study and supervision of the fur-seal herd. Our lack of knowledge of many of the essential facts in the life history of those interesting animals was pointed out again and again. The government was urged to place an energetic, resourceful, carefully trained naturalist in charge of the seal islands, with one or more trained assistants, so that the seals would be under careful scientific observation for a series of years. It was also urged that the naturalist to be put in charge should be a man who had some knowledge and experience in the raising and handling of domestic stock, because it was believed that the important principles of stock raising and management will be found to apply to the fur seal. This recommendation was made by the fur seal commissioners of 1891,

1892, 1896–97; by Captain Hooper of the Revenue Cutter service, the Bureau of Fisheries, the Advisory Board of the Fur Seal Service, and by many other naturalists. But it was not until 1910, when Charles Nagel was Secretary of Commerce and George M. Bowers Commissioner of Fisheries, that any attention was paid to this recommendation. A naturalist was then provided and serious, continued study of the fur seals was began and continued until Wm. C. Redfield became Secretary of Commerce. One of Mr. Redfield's first acts was to abolish the position of naturalist on the seal islands and to stop practically all natural history studies on the islands. Since 1913, the agents on the islands have been discouraged from making any study of the natural history of the islands; indeed, in one case at least, it is said that an agent who is a trained naturalist and who desired to carry on biological investigations and study of the seal and other animals of the islands, was ordered not to do so. (It is perhaps needless to say these orders were verbal; they were not put in writing.)

Perhaps the most discouraging condition with which we

FUR SEAL FANNING ITSELF ON A WARM DAY.
Polovina rookery, St. Paul Island, August, 1917. Photo by Hanna.

BULLS FIGHTING ON ROOKERY ON ST. PAUL ISLAND, July, 1916. When there are more bulls than are needed for breeding purposes vicious fighting results in which breeding cows are injured, pups trampled to death, and great injury done to the rookeries. This is one of the deplorable results of the very unwise law of 1912 which prohibited the killing of the surplus males. Photo by Hanna.

have to deal is the attitude of the average congressman and the average department head toward science and scientific men. Perhaps scientific men have only themselves to blame for this.

During the past thirty years there have been numerous fur-seal hearings before committees of Congress. The printed records of these hearings total many thousand pages. The cost of the hearings has exceeded half a million dollars. Many scientific men appeared before these committees, including practically every naturalist who has ever visited the seal islands. They were unanimous in their views and their recommendations as to the questions at issue. Nevertheless, their views were rarely accepted by the partisan committees, and Secretary Redfield even penalized the officials in the Bureau of Fisheries who expressed views in harmony with those of the other naturalists who testified.

This lack on the part of congressmen and heads of government departments to appreciate science or scientific men is all too common. The scientific men who came in touch with government departments during the Great War know how true this is.

But, as I have said, perhaps the scientific men are themselves largely responsible for this attitude of our law makers and executives. If so, it is largely because of their extreme

modesty and dislike to enter into controversy with the powers that be.

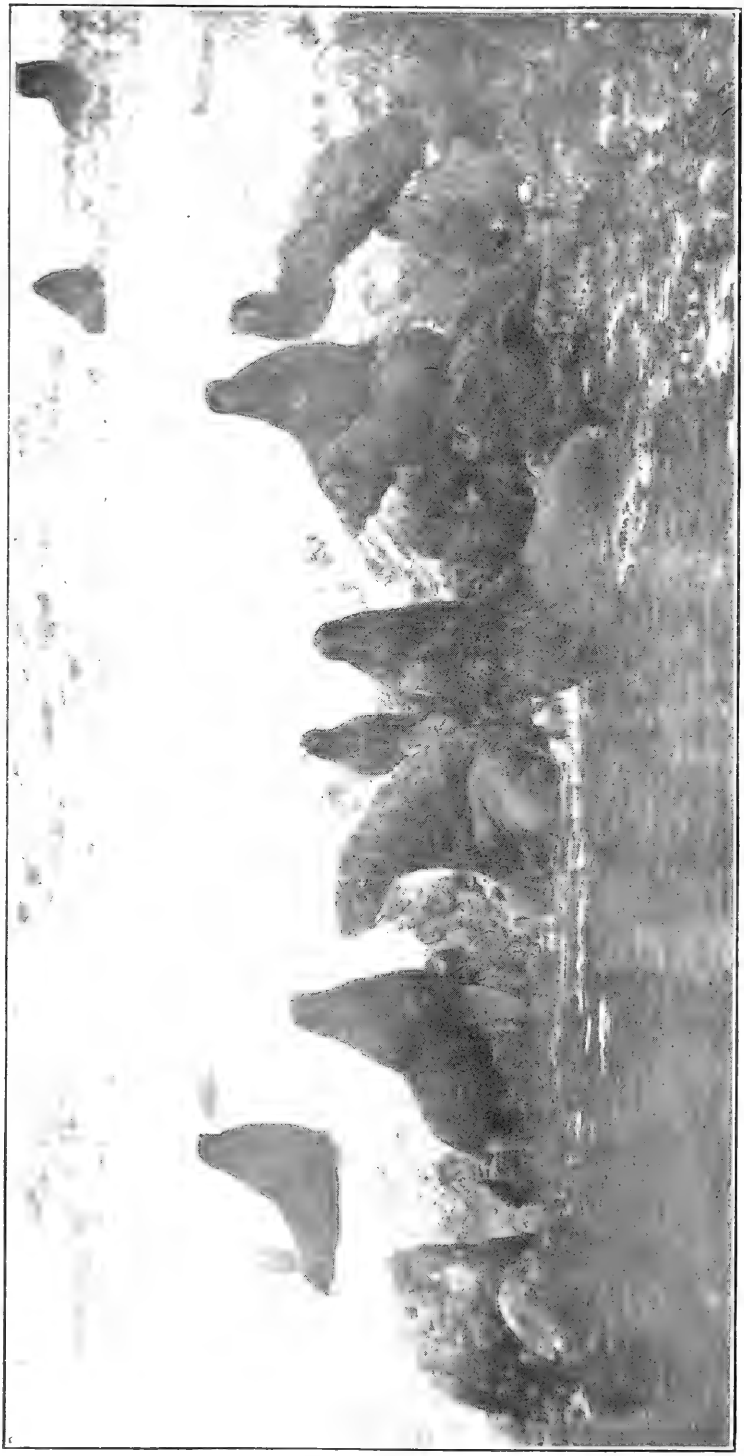
The third serious mistake which our government made was its failure to realize that the fur-seal question is one that concerns a good many countries. In 1892 and 1893, our statesmen thought it concerned only the United States and Great Britain. Japan wanted to join the United States and Great Britain in the Treaty of 1892, but she was virtually told it was no concern of hers. Japan was thus left free to engage in pelagic sealing, and she promptly entered the field, with most disastrous results to the herd.

The Paris Tribunal also was a Failure

Before this tribunal the United States lost on every count of any importance. Naturalists and other experts had been called upon to supply data for the use of the commissioners and they did so, but were not permitted to be present in person and present the facts. The result was that when our commissioners and lawyers who possessed only information, instead of knowledge, concerning the fur seal, presented their case to the tribunal they were easily confounded by the British whose experts were at hand.

Our representatives were able men, to be sure, but through lack of scientific training and appreciation of science, they were not able to evaluate the biological data furnished them by

Bachelor seals or Holluschickie, being driven to the killing grounds. Photo by Chichester.



RUSSIAN FUR SEALS LANDING AT PALATA ROOKERY. Copper Island, June 4, 1892. Photo by Evermann.

the naturalists or to present the data logically and convincingly to the tribunal. The British were more wise because they depended more upon their naturalists.

The Paris Tribunal Regulations were an absolute failure for the same reason. Our representatives would not listen to the Americans who knew most about the habits of the fur seal and who were best able to advise them.

In this treaty of 1911 which abolished pelagic sealing, our commissioners were more successful. They were more successful because they more clearly appreciated the fact that the fur-seal question is primarily a scientific question, and they availed themselves of the services of the naturalists who were most familiar with the life history of the fur seal. These men were depended upon by our commissioners to a greater extent than ever before. The treaty is a good one. The serious mistake that was made was the failure to invite China, Mexico and several other countries to join in the treaty, as was urged by the naturalists. Who can say how long it will be before sealing schooners outfitted in China, Mexico, Peru or Chili, and flying the flags of those countries, may play havoc with our fur-seal herd? There is nothing to prevent them doing so; they have a perfect right to do so; and now that the herd has again grown to considerable size, the large profits from pelagic sealing are sure to appeal strongly to adventurous characters in those countries.

In short, Washington has not realized that the fur-seal problem is one which concerns or may concern every nation bordering on the Pacific.

The next and most inexcusable mistake of our government was made in the act approved August 24, 1912, giving effect to the treaty of 1911.

In that act two very unwise provisions were included. The first of these provided for a close season of five years (1912 to 1916) in which no commercial killing on the islands was permitted; the other provided that there shall be reserved for breeding purposes each year from 1917 to 1926, 5,000 young male seals.

As to the close season, it was not only unnecessary, it was actually harmful. There was already an excess of breeding males. To save all the males born each year is as absurd as it would be for a poultry raiser to save all the roosters that are hatched. The result has been that there are now several thousand more bulls than are needed for breeding purposes.

And the saving of 5,000 young bulls each year up to 1926, to grow up into breeding bulls will increase the number of breed-

A Cow Fur Seal and her Pup.

ing bulls enormously beyond the needs of the herd. The presence of surplus bulls about the rookeries always results in severe fighting, causing injury to the cows, tramping pups to death, and general demoralization of the harems. The census of 1918 disclosed more than 2,000 dead pups, most of which had been trampled to death.

There was only one man who had ever been to the seal islands who advocated a close season and the large reservation of males, and his purpose was *not* the preservation of the fur-seal herd. Every naturalist in America who was familiar with the habits of the fur seal strongly protested against both measures, as did also Hon. Charles Nagel, then Secretary of Commerce, and Hon. Geo. M. Bowers, Commissioner of Fisheries, but without avail. When Wm. C. Redfield became Secretary of Commerce, he was urged to recommend the repeal of those provisions of the law. But Mr. Redfield, when a member of Congress, had voted for the close season. And after becoming Secretary of Commerce, he had pronounced the "close season law as very wise and sound legislation for the protection of our seal herds." However, on May 26, 1914, he appointed a commission of three eminent naturalists to visit the seal islands. The men appointed were selected "because, not having previously been identified with, or in any way concerned with fur seals or the fur-seal controversy," and it was expected that their "observations and conclusions would be uninfluenced by the past contentions." Their main duty was "to ascertain the actual state of the herd in 1914," and to submit to the Secretary of Commerce upon their return "recommendations touching all important administrative matters growing out of the international, economic, and biological relations of the seal herd," and especially regarding "the strength of the surplus male life is relation to the close-time provisions of existing law and to treaty obligation."

Before proceeding to the islands, these naturalists were warned not to talk with any one who had ever visited the seal islands or who had any personal knowledge of fur seals. They were, however, very diplomatically made acquainted with the views of the secretary; that he had voted for the close season law, that he was on record as saying that that law was "very wise and sound legislation for the protection of our seal herds," He had already taken positive stand on the matter and apparently believed that his special commissioners, knowing his position, would be accommodating and sustain him in his views.

But these three able naturalists were not of the type of men with which politicians usually deal. They were investigators.

The secretary did not know that scientific men search for truth and, when found, proclaim it. These men went to the seal islands seeking truth. They made their investigations and, upon their return, promptly submitted their report. They found that the close-season law, instead of being "wise and sound legislation" was just the opposite, and *unanimously recommended its immediate repeal!*

Although the report was received by the secretary in ample time for him to have gotten action, he pigeon-holed the report and did not transmit it to Congress until February 17, only a few days before Congress adjourned. And when he did transmit the report to Congress, he studiously avoided calling attention to any of the recommendations made by the investigators and refrained from making any recommendations of his own, although his letter of transmittal contains 600 words!

The close-season law had already been in force two years and had already caused a loss of more than a million dollars to the government and great injury to the herd. But the secretary contemptuously ignored the recommendations of experts of his own choosing and permitted the pernicious law to run its disastrous course. There were already many more bulls than were needed for breeding purposes. Thousands of pups were being trampled to death every year. The actual money loss to the United States has exceeded $3,000,000, to say nothing of the injury to the herd; and the loss to Great Britain and Japan has been at least $450,000 each.

But it is hoped and believed that, as one of the results of the world war, law makers and executives will hereafter be more appreciative of science and scientific men. No question is settled until it is settled right. This is no more true of any question than it is of those questions which relate to biological science. There are many such questions or problems in marine zoology. The fur-seal problem is only one of them. The walrus, the sea otter, the several species of sea lions and hair seals including the elephant seal, the whales and the porpoises, all these are animals that spend all or at least part of their lives beyond the three-mile limit. Our knowledge of not one of these interesting animals is such as is necessary to enable us to make proper laws and regulations for its maximum utilization consistent with the adequate conservation of the species. As they are found beyond the three-mile zone, they are subjects for international study and regulation. The same is true of all the important fisheries, such as the cod, halibut, herring, salmon, tuna and many others.

THE PROGRESS OF SCIENCE

THE LE CONTE MEMORIAL LECTURES IN THE YOSEMITE VALLEY

Joseph Le Conte, one of the most distinguished of American naturalists, for thirty years professor in the University of California, died in the Yosemite Valley, and the Sierra Club erected there a memorial lodge in his honor. The University of California has now arranged to give each year at the lodge a series of lectures, to be known as the Le Conte Memorial Lectures, and the first course has been completed.

The area in front of the memorial lodge proved an admirable setting. The lectures were given in the early twilight hour, from 7:30 to 8:30, when the sunset made the whole valley radiant. It is estimated that the average attendance at the lectures was fully one tenth of the large visitant population of Yosemite this year. It was about 275 people, with the exception of Dr. Bade's address on "John Muir's Services to the Nation," which was heard by fully 1,500. The speakers are all men of recognized standing in their fields. Each gave a series of three lectures, making twelve lectures in all.

Dr. Willis L. Jepson, the opening lecturer, gave three addresses: "Some Flowers of the Yosemite," "The Biology of the Chaparral" and "The Ancestry of the Pines and Sequoias in the Yosemite."

"John Muir, Nature and Yosemite" constituted the general topic of the three lectures by Dr. William Frederic Bade, the literary executor

The Le Conte Memorial Lodge.

of John Muir. In his first address he gave an account of the life of Muir, and a description of the methods of thought and study whereby he came to possess an intimate knowledge of the Yosemite and the whole Sierra region. Dr. Bade's lecture, "John Muir's Services to the Nation," constituted the oration of the day at a Fourth of July celebration. He told how Muir had toiled for the establishment of national parks, and gave an account of his cooperation with Theodore Roosevelt in attaining that end.

The next series of lectures was delivered by François E. Matthes, geologist of the United States Geological Survey. Mr. Matthes' knowledge of the Yosemite area is particularly complete, owing to the fact that he has been making careful studies of that region for nearly sixteen years. He is the author of the most authentic map of the Sierra region which includes the Yosemite. In his first address, "The Origin of the Yosemite Valley," aided by stereopticon views, he gave a complete account of the forces which created the Sierra range and showed how the tilting of the Sierra fault had accelerated the fall of the rivers down their western slope. Drawing his deductions from the "hanging valleys" from which the great waterfalls of the Yosemite plunge, he worked out the history of those processes of nature whereby for ages the valley was carved—first of all by the Merced River, and later in glacial times by the passing of the great ice floods.

His second was delivered at Glacier Point at an elevation of over seven thousand feet above sea level. Despite the difficulty of access to the place where the lecture was given, upwards of three hundred people climbed to Glacier Point to hear him. Standing on a rock overlooking the entire valley, Mr. Matthes showed how, fifty to one hundred thousand years ago, the great glaciers swept over the western slope of the Sierra and carved the valleys. The concluding geological lecture was on "The Origin of the Granite Domes of Yosemite."

The final series in the course, "The Indian Tribes and Folk Lore of the Sierra," was by Dr. A. L. Kroeber, professor of anthropology. In his first lecture he gave an account of the various tribes of Indians of California. The second address, "The Indians of Yosemite," was devoted to those tribes, Tenayas and Monos, which have for many generations made the Yosemite area their home. In his third lecture he gave an interesting discussion of the Indian legends and folk tales that haunt the Yosemite, reciting a number of them for the benefit of his hearers.

THE DIRECTORSHIP OF THE BRITISH NATURAL HISTORY MUSEUM

Dr. Sidney Frederick Harmer, since 1907 keeper of zoology, has been elected director of the natural history departments of the British Museum. Dr. Harmer was born in 1862 and received his academic degrees at London and Cambridge. At Cambridge he became fellow of King's College, lecturer in zoology and superintendent of the university museum of zoology. With Dr. A. E. Shipley, master of Christ's College and now vice-chancellor of the university, he edited the Cambridge Natural History. He is an authority on invertebrate zoology, especially on the polyzoa, and on the natural history and conservation of sea animals.

The directorship of the British Natural History Museum thus maintains the traditions set by Sir Richard Owen, Sir William Flower, Sir Ray Lankester, Sir Lazarus

Dr. Sidney Frederick Harmer,
Director of the British Natural History Museum.

Fletcher, even though their names may not be a series ascending in scientific distinction. The trustees had, however, planned to elect as director an executive officer of the museum without scientific qualification, passing over Dr. A. Smith Woodward, Dr. Harmer and other scientific men of the institution and of the country. They were prevented from doing so by vigorous protests from scientific men, a large number of leaders having, for example, signed a letter in which they said that to appoint a staff officer instead of a man of scientific standing would be "an affront to scientific men and of grave detriment to science."

The electing trustees of the British Museum are the Lord Chancellor, the Archbishop of Canterbury, and the Speaker of the House of Commons, and it is perhaps not surprising if they do not have expert qualifications for the conduct of a scientific institution. An English journal—*The Naturalist*—remarks: "In the old days when all our national collections were housed at Bloomsbury, and books and mummies were the chief attraction, a Chancellor, an Archbishop and a Speaker may have been a suitable tribunal. But science has made leaps and has bounded away to South Kensington since then, and the present government should see to it that the appointment of the director of the Natural History Museum is in the hands of men capable of judging the requirements of the post, instead of, as in the present case, attempting to give the honor to the person who salaams to them on the few occasions upon which they meet, and who has the privilege of recording the Great Words which issue from their Great Mouths."

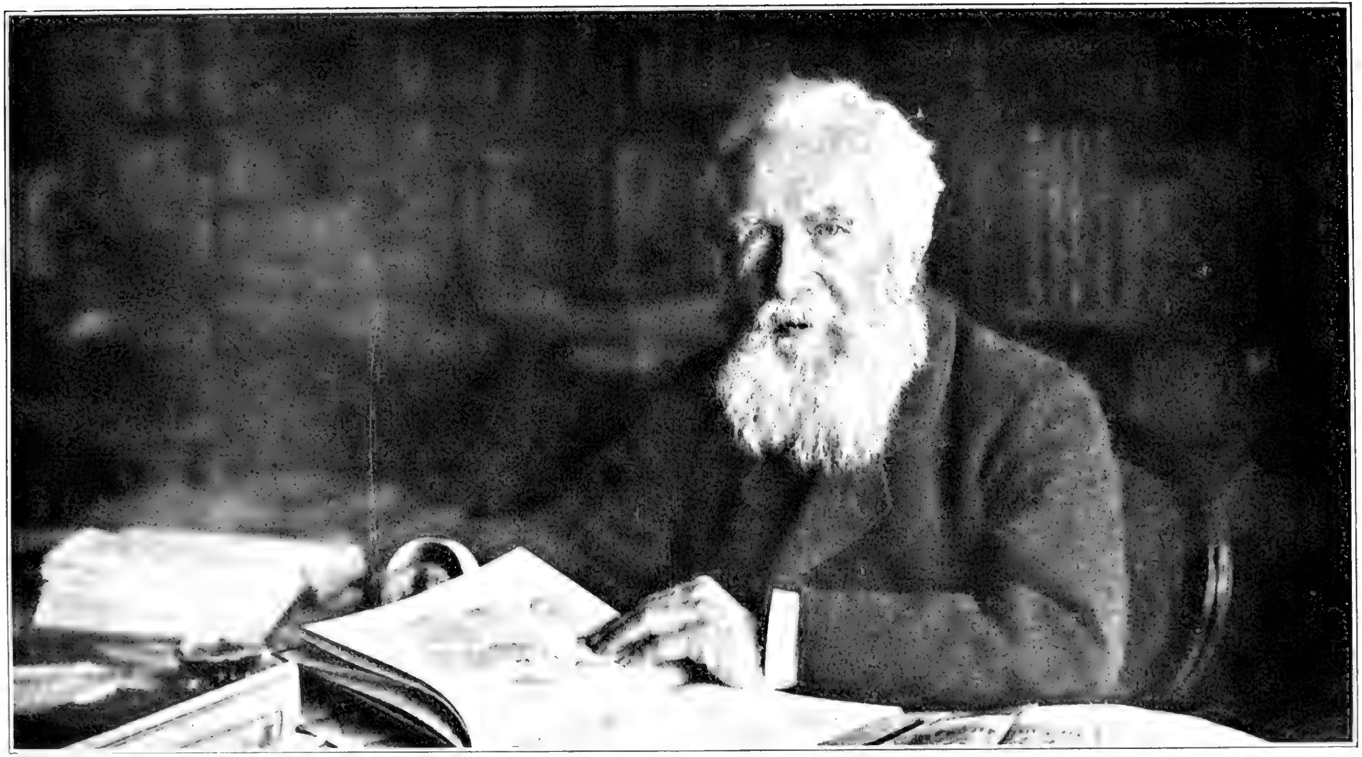
It might be well if we should learn from the English situation, for we have a National Museum, which is subsidiary to the Smithsonian Institution, whose regents are not scientific men. It now has a magnificent building and good collections; excellent scientific work is accomplished; but it has no director. Dr. G. Brown Goode, who was in charge as assistant secretary of the Smithsonian Institution, was an admirable museum administrator and he was worthily succeeded by the late Dr. Richard Rathbun. But there seems to be no movement to place the museum in control of a director eminent in science.

USE OF THE GEOPHONE BY THE BUREAU OF MINES

THE geophone, a listening instrument invented by the French during the war to detect enemy sapping and underground mining operations and for the location of enemy artillery, is now being used by the Bureau of Mines, Department of the Interior, as a possible aid in locating miners who have been entombed after a disaster. The instrument was developed by the United States engineers during the war and is now used by the bureau according to plans drawn by them.

Alan Leighton, assistant chemist of the bureau, who now has charge of these investigations, reports that the instrument, though small, is essentially a seismograph, since it works on the same principle as the ponderous apparatus with which earthquake tremors are recorded. It consists of an iron ring about three and a half inches in diameter, within the center of which is suspended a lead disk which is fastened by a single bolt through two mica discs, one of which covers the top and the other the bottom of the ring. There then are two brass cap pieces, the top one having an opening in its center to which is fastened a rubber tube, leading to a stethoscopic ear piece.

We then have really nothing but



Ernst Heinrich Haeckel,

Professor of zoology at the University of Jena since 1865, who has died at the age of eighty-five years

a lead weight suspended between two mica discs cutting across a small air-tight box. If the instrument is placed on the ground and any one is pounding or digging in the vicinity, energy is transmitted as wave motion to the earth, and the earth-waves shake the geophone case. The lead weight, on account of its mass and because it is suspended between the mica remains comparatively motionless. There then is produced a relative motion between the instrument case and the lead weight. The result is that a compression and rarefaction of the air in the instrument takes place. Since the rubber tube leading to the stethoscopic ear piece is connected with this space in the geophone, this rarefaction and compression is carried to the ear drum. Usually two instruments are used, one for each ear.

When the two instruments are used, it has been found that the sound is apparently louder from the instrument nearer the source of the sound. It is evident then that by moving the instruments properly a point can be found when the sound will be of the same apparent intensity in both ears. The direction of the sound is then on a perpendicular to the line connecting the centers of the two instruments either in front of or behind the observer. Further observation will show which side. Direction is quite accurately determined in this way. The sound is not actually louder in one ear than in the other, but the ear is capable of distinguishing the difference in time at which the sound arrives in the two instruments.

During the period of the war, engineers of the Mining Division of the Bureau of Mines were engaged in determining the distance that different mining machines could be heard through the clay, shale, coal and the mine cover. Measurements were made also of the energy required in blows that they be heard definite distances through clay, shale and coal, as well as the distances at which the shock waves resulting from the discharge of various explosives could be heard. A brief investigation of the factors influencing the transfer of energy from a mining tool to the clay and coal was also made in order that recommendations could be made as to the type of mining machine which could be used to accomplish the most work with the least noise.

SCIENTIFIC ITEMS

We record with regret the death of Emil Fischer, professor of chemistry in the University of Berlin, and Adrian J. Brown, professor of the fermentation industries at the University of Birmingham.

Dr. John Campbell Merriam, professor of paleontology and historical geology in the University of California, who has been acting chairman of the National Council of Research, was elected president of the Pacific Division of the American Association for the Advancement of Science at the Pasadena meeting.—On the occasion of the seventieth birthday of Sir William Osler, regius professor at Oxford University and previously professor in the Johns Hopkins University, which occurred on July 12, he was presented with a collection of essays contributed by about one hundred of his pupils and colleagues.

George Eastman, head of the Eastman Kodak Company, has given the sum of $3,500,000 for the establishment of a school of music in connection with the University of Rochester. The school will aim to aid the development of an appreciation of the highest type of motion pictures as an ally of the highest type of music.

THE SCIENTIFIC MONTHLY

OCTOBER, 1919

THE ORIGINS OF CIVILIZATION [1]

By Professor JAMES HENRY BREASTED

THE UNIVERSITY OF CHICAGO

FROM THE OLD STONE AGE TO THE DAWN OF CIVILIZATION

I.

LINNÆUS was the first natural scientist to find a place for man in the natural system. There is an enormously long stage in the career of man when the study of him is obviously the task of the natural scientist. Much of the work of the anthropologist and psychologist is properly classed as natural science. At a certain stage in the development of man, however, we begin to call the study of him and his works archeology, history, philology, art and literature—lines of study which we sharply differentiate from natural science. I have often wondered what there is unnatural about man. If it could be demonstrated that the pterodactyl was gregarious, built towns, made pottery, carried on industry and commerce, and left behind written records, I fancy that we should still call the study of him paleontology and not divorce it from natural science.

It has been a source of great gratification to the writer that in the William Ellery Hale lectures on Evolution, the career of man has been regarded as a part of the course of nature. The protoplasm is indeed a long way from the idea of liberty and the chimpanzee may antedate by millions of years the conception of social justice, but the transition from the stage of biological to that of social processes is a gradual one, even though we readily recognize that man has finally risen to many qualities and ideas which transcend matter and can not be placed under the microscope or weighed in the chemist's balances.

[1] Delivered before the National Academy of Sciences in Washington, D. C., April 28 and 29, 1919, as the seventh series of lectures on the William Ellery Hale Foundation.

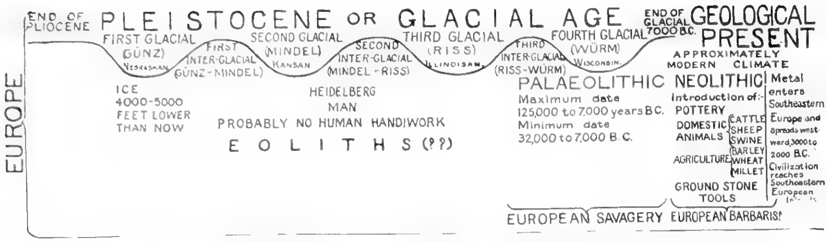


Fig. 1. Diagram of the European Glacial Age.

The archeologist depends on stratification just as the geologist does. He dates his strata not only by superposition, but also by the artifacts contained in them, precisely as the geologist dates his strata by the fossils they contain. As we all know, the prehistoric archeologist and the geologist work side by side, and each gladly accepts the other's results. This association brings us orientalists into intimate relations with natural science, for we carry on the work of research in the Near Orient, having, on the one hand, early prehistoric man *preceding* ancient Oriental civilization, and, on the other hand, historic Europe *following* the ancient Orient. The early Oriental civilizations thus occupy a place between the remote savagery of prehistoric Europe and the civilized career of historic Europe beginning in Greece and Italy.

My distinguished predecessors have carried the progressive development of matter through the origins of life and its evolution to ever higher forms, and have thus finally reached the early stages of the first implement-fashioning creature, which we call man. He has been followed by means of the trail of stone implements which he began to leave behind him, through the successive advances and retreats of the ice in the glacial epoch, oscillating like the pendulum of a vast geological clock, and thus measuring for us in large and still unprecise periods the several hundred thousand years of the discernible human career.

In the long struggle with the hostile forces of nature about him, the savage European hunter of the Paleolithic Age had slowly advanced through successive improvements of his weapons and tools of stone, bone, horn, ivory and wood, until the final retreat of the ice some seven or eight thousand years before the Christian era (Fig. 1). In spite of the remarkable progress which he had made and his surprising achievements in art, as illustrated in the wonderful cave paintings of southern France and northern Spain, it is evident that his general progress had been retarded as contrasted with the development of

the hunters of the Paleolithic Age on the south side of the Mediterranean. It is a natural conclusion that the retarding force was the recurring cold and ice by which Europe was so long beset, while the south side of the Mediterranean was enjoying far more genial conditions. It will therefore be necessary for us to investigate what was going on in northern Africa, long before the last glaciation of Europe had retreated. The presence of the great African mammals in glacial Europe, like the southern elephant (*Elephas meridionalis*) whose bones are found on the high terraces of the Seine and the Eure ninety feet above the present river level, demonstrates the connection of Europe with Africa in that distant age. Both at Gibraltar and through Sicily the great European peninsulas of the western Mediterranean were united with Africa by land (Fig. 2).

Just as the wild creatures crossed these land bridges from Africa to Europe and back again, so must the men who hunted them have done. The dispersion of the art of chipping flint implements throughout the contiguous areas of the two continents was a matter of course. Let it be clearly stated, however, that this unquestionable fact does not carry with it the conclu-

FIG. 2. MAP OF INTER-GLACIAL EUROPE. (After Geikie.) Showing landbridges between western Europe and Africa.

sion that the stages of prehistoric culture on both sides of the Mediterranean necessarily kept even pace with each other, and were therefore always contemporaneous. This we know was not true as between North and South America; neither was it true of prehistoric Africa and Europe. When the European Stone Age hunters received metal in the Ægean area about 3000 B.C., it was a thousand years before it had crossed Europe to Scandinavia and the British Isles. To speak of Mousterian flints found in Siberia as necessarily contemporary with those of France, is as absurd as to make Verestchagin, the Russian painter, contemporary with Titian.

The existence of North African man in European glacial times has been clearly demonstrated. The flint implements which he wrought have been found, still lying in strata of quaternary age in Algiers.[2] In the caves of Gafsa in Tunis Schweinfurth has also found flints of Paleolithic type, but not in stratifications or with a fauna which demonstrates their unquestionable Paleolithic age.[3] In the same region, furthermore, Schweinfurth has found artifacts of even pre-Chellean types, lying in deposits of coarse conglomerate (*nagelfluh* or "*poudingue*" Fr.), which the discoverer concludes were of early quaternary date. He found 411 pieces, some of which he classifies as Eoliths and everything else as Chellean or pre-Chellean.[4]

These early Stone Age hunters of North Africa have left more than their stone implements to tell of their existence along the southern shores of the Mediterranean. In Algiers they carved in the natural rock faces rude drawings of the animals they were daily pursuing. One of these prehistoric drawings (Fig. 3) shows us the *Bubalus antiquus*, or ancient buffalo, a creature presumably of quaternary age in this region. This again demonstrates the presence of Paleolithic hunters in North Africa.[5]

It is evident that the Sahara desert during the age represented by such remains, must have been a fertile region, with productive soil and plentiful precipitation. This continued until the latter part of the glacial epoch; but in the last glaciation of Europe the climate along the Nile at least, was nearer that of to-day. Graffiti and Neolithic remains in the western

[2] See Boule, *L'Anthropologie*, 13, 1902, pp. 109–110, against Forbes, *Bull. Liverpool Mus.*, III., 1901, No. 2.

[3] Schweinfurth, *Zeitschr. f. Ethn.*, 39, 1907, pp. 899–915.

[4] Schweinfurth, *ibid.*, 39, 1907, pp. 137–181.

[5] Pomel, *L'Anthropologie*, XI., also Obermaier, "Mensch der Vorzeit," p. 168.

Sahara would indicate its habitability, however, in time relatively recent, as the Neolithic of this region seems to have continued almost down to modern times.[6] Gautier concludes that the changes here have not been due to alteration of the climate during the last two thousand years, but to desiccation caused by dunes, cutting off the Sudan from the Sahara, and resulting in its absorption by the Berbers from the north.

The probabilities certainly are that fertile conditions in the Sahara during the major portion of the Pleistocene permitted the distribution of the Paleolithic hunters from Algiers to the

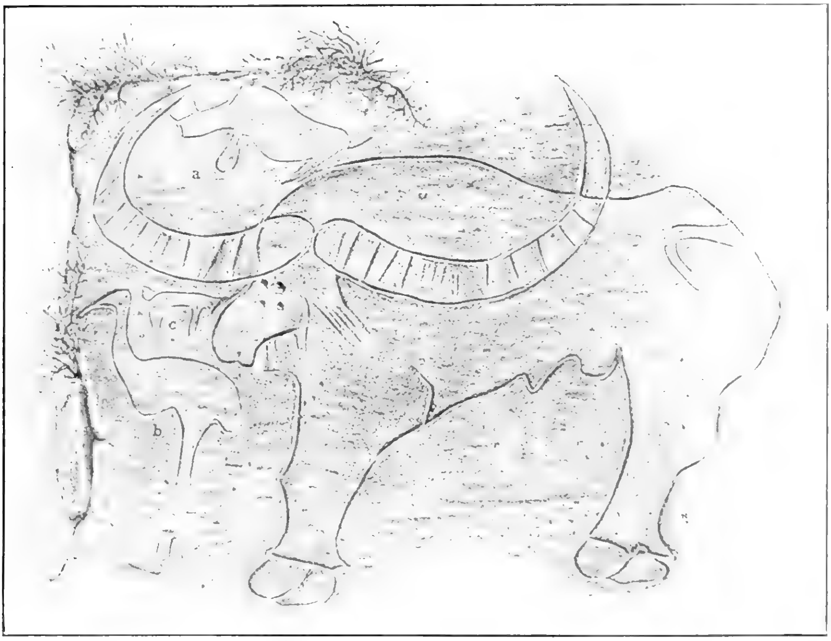


FIG. 3. ROCK GRAFFITO OF THE WILD BUFFALO (*Bubalus Antiquus*) IN ALGIERS. Carved by prehistoric hunters in the Palæolithic Age. (After Por.)

Nile. But the Nile of that period offers a geological history which we must have in mind, because it went hand in hand with the career of man in northeastern Africa.

During or just before the formation of the lower levels of the Upper Pliocene, while the Mediterranean coast line was at the site of later Cairo, two extensive fractures occurred, varying from 7 to 24 km. apart. They extended southward from the coast some four hundred miles to the vicinity of Keneh, forming what is called a "block fault" in the earth's crust. As the block between the fractures sank it formed a great rift

[6] E. F. Gautier, *L'Anthropologie*, 18 (1907), pp. 37–68, 314–332.

FIG. 4. MAP OF THE EGYPTIAN RIFT IN PLIOCENE-PLEISTOCENE TIMES. (After Blanckenhorn.)

or trench, stretching from the sea shore at the site of modern Cairo in latitude 30° N., to Keneh in latitude 26° 7′ N. (Fig. 4). The entire rift is in the Eocene limestone. Other more local faults of varying origin carried the rift above Thebes, south of which (at Gebelen) it narrows. Measured along its bends the entire trench is almost 450 miles long. (Railway distance from Cairo to Luxor is 416 miles, and Gebelen is over 17 miles above Luxor.)

As Blanckenhorn, to whom we chiefly owe these facts, has shown,[7] the rift was open to the sea, which entered and penetrated as far south as Dahaibe, then about ninety miles from the sea shore. Here must have been for a time the earliest mouth of the Nile. But this was much later. The intrusion of the sea fell in the transition from the upper Middle Pliocene to

[7] Blanckenhorn, "Geschichte des Nil-Stroms," in *Zeitschrift der Gesell. für Erdkunde,* 1902, pp. 694–722 and 753–762.

the lower Upper Pliocene. It was contemporaneous with the beginning of increased precipitation in the Upper Pliocene, followed by the rainy transition period from the Pliocene to the Pleistocene, which Hull has called the Pluvial Period.

The narrow connection of the new Egyptian fjord with the sea was early largely blocked and the rapidly gathering fresh water of the east and northeast African drainage soon filled the rift and formed a large lake or series of lakes stretching from the region of Thebes to the sea. Into this lake or lakes plentiful streams flowed from east and west, carrying into the great trench extensive masses of conglomerates, gravels, marls, limestones, etc., which covered the bottom of the trench, and formed also in massive terraces of alternating limestone and indurated gravel along the walls of the rift (Fig. 5).

The characteristic fossil contained in these deposits is the lacustrine mollusc *Melanopsis*, the period of whose prevalence in this region seems to correspond to the already climatically cooled Upper Pliocene and Early Pleistocene especially of the first glaciation in Europe. This is at least the current and probable hypothesis. Accepting this probability, the earliest, that is to say the lacustrine, terraces of the Egyptian trench belong to late Pliocene and early Pleistocene times.

In the immediately succeeding drier period, corresponding to one of the early glacial periods (perhaps the first Inter-Glacial), the Nile stream for the first time appeared in this Egyptian rift. From this time on, river terraces were formed along its banks, though in relatively limited extent. Two of these river terraces can be discerned between the lacustrine terrace above and the alluvium below. The *higher* river terrace is from 6 to 30 m. (along its lower edge) above the level of the

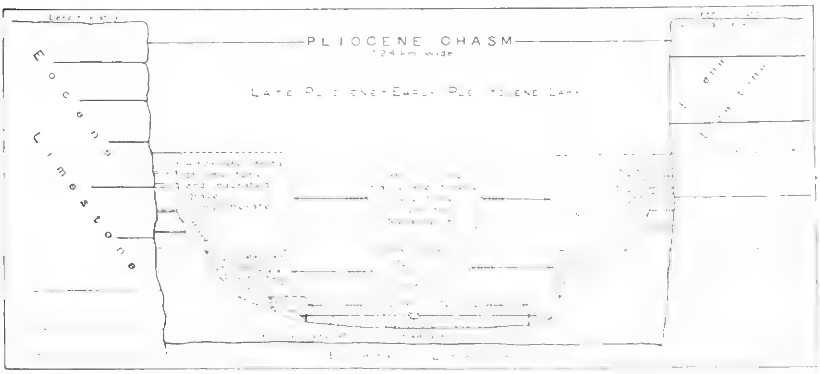


FIG. 5. SCHEMATIC CROSS-SECTION OF THE EGYPTIAN RIFT.

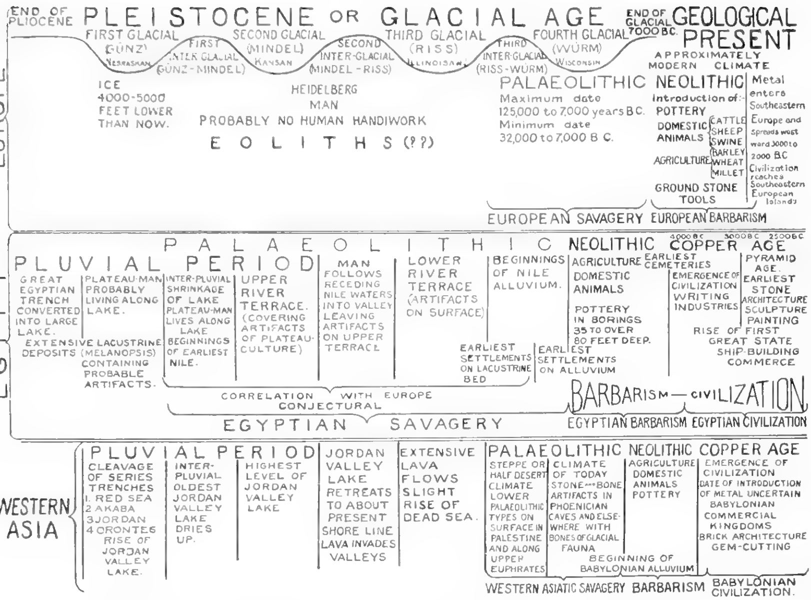


FIG. 6. DIAGRAM SHOWING ATTEMPTED CORRELATION OF GLACIAL EUROPE AND EGYPT.

alluvium; the *lower* is only 9 to 10 m. above the alluvium. The lower of the two is not everywhere observable or distinguishable, for like the typical Nile alluvium it also is made up of Nile mud, sand and fine gravel, without any coarse rubble, and it emerges as a more or less wide, gentle slope along the edge of the cultivated land, and is therefore not sharply distinguished from the latter.

The fauna of these Pleistocene deposits is confined as a rule to shells of fresh-water molluscs still living in the Nile. To these may be added only one extinct variety, the *Unio Schweinfurthi* (Martens). Very few remains of mammals have been found in deposits of this age, but they include buffalo horns and teeth of the hippo and elephant, while the marly lake deposits of the Fayum have yielded teeth, hoofs and leg bones of the horse. With these was also found the mandible of a man, later unfortunately lost. A comparison of this fauna with that of Syria has led Blanckenhorn to the conjecture, if not to the conclusion that in these southern lands, especially Egypt, there did not develop a pleistocene fauna analogous to that of glacial Europe—as if the climatic conditions, at least in the later Pleistocene, the time of prehistoric man, were not so different from those of to-day as in glaciated Europe.

After the formation of the two river terraces shown in the

cross section (Fig. 5), the Nile began laying down the present alluvial floor of the valley. For the deposit of this deep stratum of alluvium, varying from some thirty feet in depth at Thebes to over a hundred or even over a hundred and thirty feet in the Delta, it is evident that the relatively brief period since the retreat of the ice in Europe was quite insufficient. Blanckenhorn estimates that the lower half of the clayey sands and sandy clays forming so much of the Nile alluvium was deposited during the last glacial period of Europe.

To summarize, it will be seen that the geology of the Nile valley, in so far as it bears on the age of man there, displays four chief periods: I., The Lacustrine Terraces (=Pliocene and First Glacial?) ; II., The Upper River Terrace (=Second Glacial?) ; III., The Lower River Terrace (=Third Glacial?) ; IV., The Alluvium, Lower (=Fourth Glacial), Upper (=Post-Glacial?).

In view of the probability that the Lacustrine (Melanopsis) stage reaches over into the First Glacial, and the certainty that the lower Alluvium reaches back into the Fourth or Last Glacial it is tempting to make the Second and Third Glacial correspond respectively to the two River Terraces (Fig. 6). The four glacial ages would then be parallel with the four main periods disclosed by the Nile deposits. These geological parallels are in no sense vital to this presentation, however, with the exception of the conclusion, clearly demonstrated by Blanckenhorn, that

Fig. 7. The Nile Valley Alluvium at Siut, seen from one of the lower river terraces.

FIG. 8. THE NILE VALLEY ALLUVIUM AT SIUT, WITH RIVER TERRACE IN FOREGROUND. (Photograph by Underwood & Underwood.)

the Lower Alluvium corresponds to the European Fourth Glacial.

Turning now to the Nile valley as we find it to-day, the view of Siut in Fig. 7 furnishes a characteristic prospect across the black alluvial floor of the Nile valley from the distant cliffs in the east, to the western cliffs from which the photograph is taken. As we step back up the slope, we include within the range of the camera one of the lower river terraces seen in the foreground of Fig. 8. Again the cliffs near Der el-Bahri at Thebes display characteristic formations of the Lacustrine Terraces, above those of the river (Fig. 10).

These terraces are clearly correlated in a geological map of the western cliffs of Thebes by Schweinfurth (Fig. 9). The band below shows the extent of the cultivated land, the alluvium; the next band above it represents the river terrace, presumably the upper, the lower disappearing at this place, while the uppermost band shows the situation of the lacustrine terraces. According to Blanckenhorn, it will be recalled, these lacustrine deposits, characterized by the fossil mollusc *Melanopsis*, were laid down in late Pliocene–early Pleistocene times; the upper levels therefore may belong in the First Glacial

Period of Europe. At that time the Sahara plateau was habitable, and discoveries of Schweinfurth would indicate that probably as early as the European First Glacial Period, men able to produce flint implements lived along the margin of the cliffs, above the lake here at Thebes.

If Schweinfurth is correct the rude artifacts produced by these men were carried by the drainage from the shores of their plateau dwellings into the lake, where they are now embedded deep in the lacustrine terraces below the brow of the cliffs. He

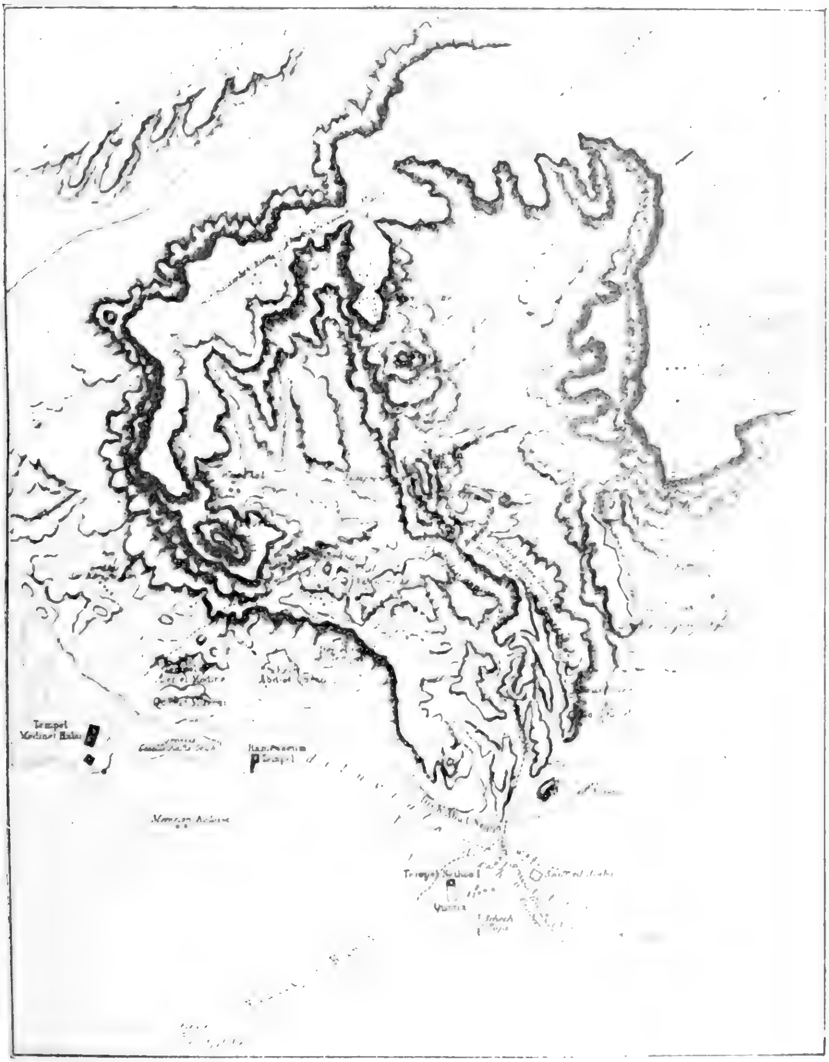


Fig. 9 Geological Map of Western Thebes. (By Schweinfurth.)

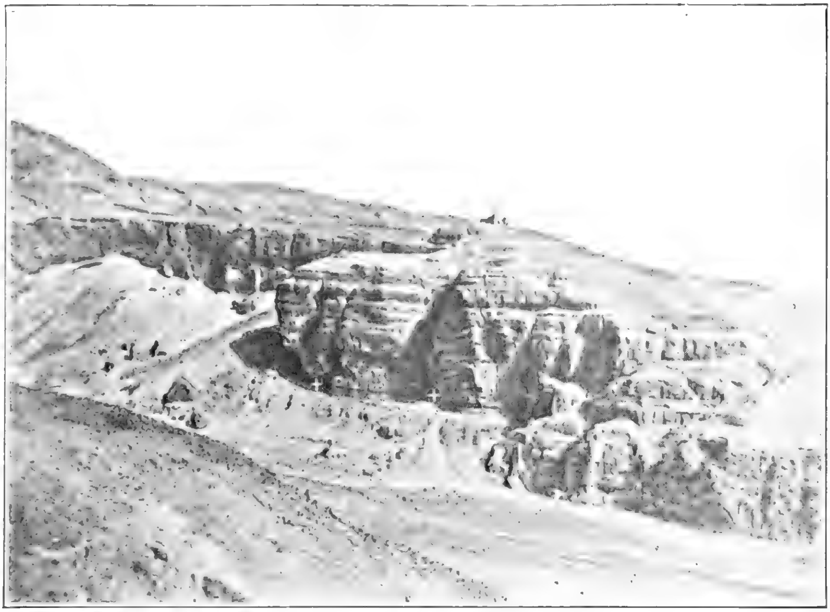


FIG. 10. THE LACUSTRINE TERRACES NEAR DER EL-BAHRI ON THE WEST SIDE AT THEBES. The levels containing artifacts are marked with a cross. (After Schweinfurth.)

has found them below several alternate strata of limestone and indurated gravel, which have collected some fifty feet or more above the artifacts (Fig. 10).

One form believed by Schweinfurth to have been produced by the hand of man displays the familiar "bulb of percussion"; while the edges show evidences of secondary flaking (Fig. 11). The fact that this region was never visited by the ice, makes it more probable that such flints were produced by man, in the absence of the grinding, the pressure and other forces of the ice, to which the European "eoliths" were subjected.

However this may be, it is certain that far back in the European Glacial Age the North African plateau was inhabited as we have already seen. Inhospitable as the stretches of the desert along the Nile valley now look, they were once the home of man. These early plateau hunters have left traces of their presence other than their flint weapons. In 1906 a native at Abu Simbel in northern Nubia assured me that he could take me out into the Sahara to an unknown temple of which so many vague reports had reached archeologists that it had long been known to us as "the lost temple." Several hours march from the Nile, far out in the western desert, we did indeed find it

(Fig. 12). It proved to be a natural rock formation, with a door wrought also by nature, and alongside the door the records which the natives had reported as inscriptions proved interesting enough. Here were carved two boats, two giraffes, two ostriches and a number of smaller animals. The giraffe has been extinct in Egypt from very remote times, and it is possible that the hunters of Pleistocene Age have left these records in the Sahara.

Just above Thebes along the crest of the cliffs behind the Kings' Tombs (Fig. 14), these early hunters had a number of workshops, and here worked flints are still scattered so plentifully that there are stretches kilometers long, where one literally walks on artifacts, and it is difficult to find a piece of flint produced by nature. The date of artifacts found thus lying on the surface is not to be determined by the shape, workmanship and type alone. Fortunately these same artifacts may also be stratigraphically dated in the immediate vicinity.

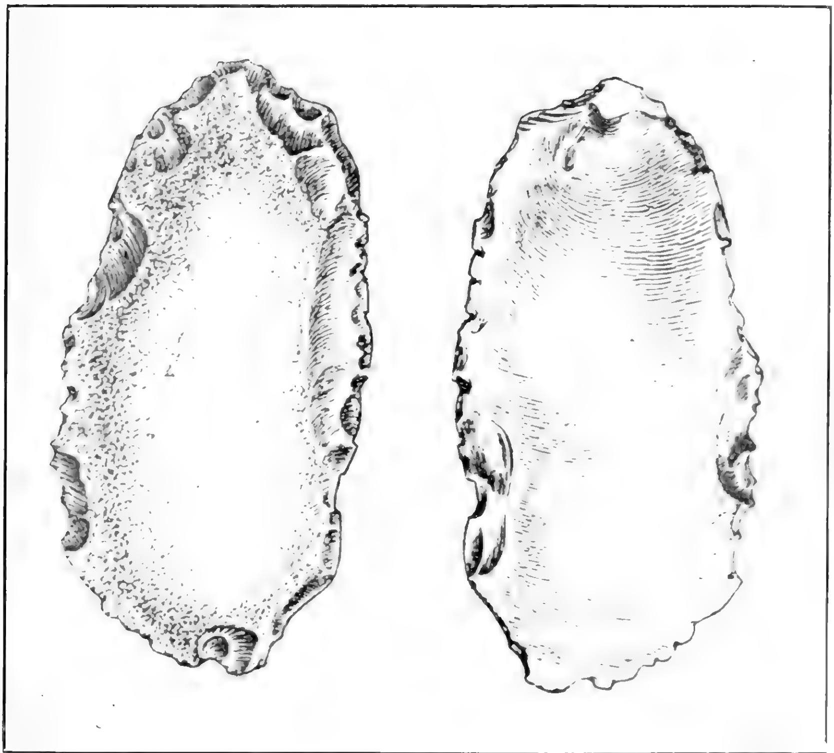


FIG. 11. HUMAN ARTIFACT FOUND WITH MANY OTHERS BY SCHWEINFURTH IN THE LACUSTRINE TERRACES OF THE NILE RIFT. They lay some fifty feet below the surface, at the point marked with a cross in Fig. 10.

Fig. 12. The So-called Lost Temple behind Abu Simbel in Lower Nubia.

As the great Egyptian lake shrank and the earliest Nile current began to move northward in the old bed of the lake, the drainage of the latter part of the Pluvial Period carried large masses of the neighboring rock rubbish into the valley, and

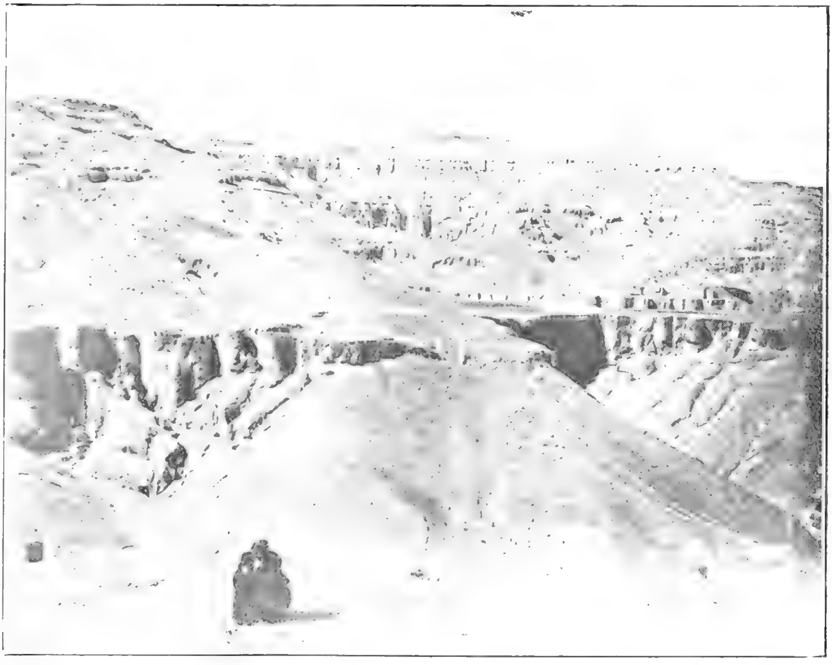


Fig. 13. The Heights of the Sahara Plateau above Thebes. Extensive flint workshops of Quarternary age have been found lying on the surface of the plateau.

these materials helped to form the Upper River Terrace. They carried down with them numbers of the flint artifacts already lying on the plateau, and these early works of man are now found embedded in the conglomerate and indurated gravels of the Upper River Terrace. They were first noticed by Gen. Pitt-Rivers as far back as 1881, at a spot marked with a cross by Schweinfurth on his map (Fig. 9) near the mouth of the wadi called el-Wadiyên ("the two wadis") north of Seti I's Temple of Kurna, on the road to the Kings' Tombs.

Little attention was paid to Pitt-Rivers' discovery; but over twenty years later Schweinfurth placed its correctness beyond

FIG. 14. ROCK-HEWN TOMB COURT KNOWN AS "SAFT EL-LEBEN." In the conglomerate walls of this court artifacts carried down by the drainage in Pleistocene times from the plateau above have been found. (Photograph by kindness of Winlock.)

all doubt. He found artifacts embedded in the strata of this river terrace at Kurna all along the lower end of the Wadiyên, and likewise in the neighboring large courts of the Egyptian tombs here. These courts are some 75 m. square, open on one side and with about twenty-five tomb doors cut in each of the remaining three sides (Fig. 14).

The investigations of Winlock of the Metropolitan Museum have made it extremely probable that these large courts and their arrangements belong to the Eleventh Dynasty (2160–2000 B.C.); that is to say they are over four thousand years old. The entire court and the tombs the doors of which are visible in

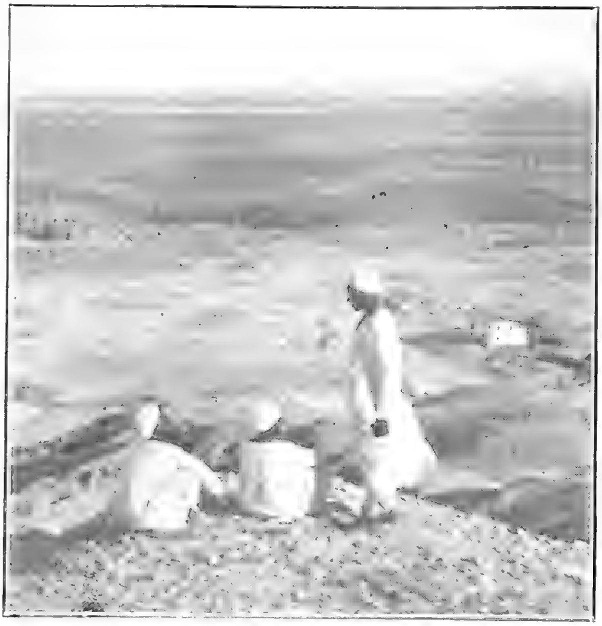


FIG. 15. RIVER TERRACE ALONG THE NILE AT THEBES. Here the plateau hunters lived when they shifted from the plateau down into the Nile Rift. (Photograph by Underwood & Underwood.)

Fig. 14 were therefore excavated from a conglomerate or "nagelfluh" formation, hard enough for such excavation over four thousand years ago. Here are thousands of square yards of wall surface embedded in which large numbers of flint artifacts may be found. It requires considerable effort with cold chisel and hammer to disengage these works of early man, thus embedded in a late rock formation.

The materials of which this conglomerate is composed show clearly that they came from the neighboring heights; and their situation at the lower end of a wadi leading down from the plateau leads to the same conclusion. Finally the artifacts contained in the formation are of the same types and workmanship as those found still lying on the plateau. The remains of man found in this terrace belong therefore to the plateau culture, and to a period of that culture long antedating the formation of the terrace.

When the Theban river terrace containing these artifacts was forming (compare Fig. 5), the earliest Nile was at least 15 to 20 meters (over 45–60 feet) above its present highest level. As the river declined in volume, probably during the Second Inter-Glacial of Europe (see Fig. 6), the plateau hunters began to

shift into the valley itself, and to occupy the stretches of terrace on the river's brink. Primeval forest alternated with marsh and jungle along a raging flood of the vast river. Here on the dry and exposed rubble heaps the plateau hunters took up their dwellings. They gradually transferred their flint workshops to the brow of the upper river terrace. Here their flint implements are still found lying on the surface (Fig. 15).

Their hearths and doubtless later their wattle huts were distributed along the river terrace not far from the cliffs behind; for the vantage ground between the foot of the cliffs and the river must have been scanty at first. It was natural that they should scratch their hunting records on the rocks of the cliffs behind their homes, and it is doubtless to this stage of human life in the Nile valley that we owe many of the game animals pictured on the rocks. At a somewhat later stage the reed floats which the former plateau hunters had learned to make for crossing the river along which they had now established their dwellings, were displaced by primitive wooden boats, the earliest known. Of these also, the hunters have carved rude pictures on the walls of the Nile rift (Fig. 16). The great age of these cliff pictures is interestingly shown by the fact that the areas cut away by the

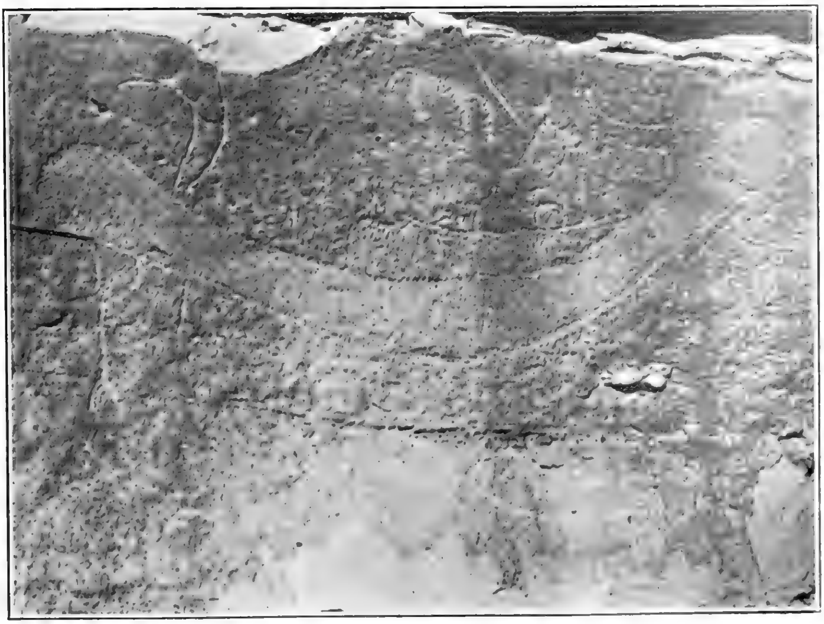


FIG. 16. CLIFF PICTURE OF A PRIMITIVE NILE HUNTER'S RUDE WOODEN BOAT. The earliest wooden craft known, cut on the cliffs at el-Kab. (After Green in *Proceedings of the Society of Biblical Archaeology*, Vol. XXV.)

ancient hunters in carving these figures are covered with a dense blackish brown patina, the somber raiment worn by all rocks in the desert and called by Walther "desert varnish." According to Lucas[8] it is due to oxides of iron and manganese dissolved out of the stone by the rare rains and the dews, and changed on the surface by the heat into ferric oxide and manganese dioxide, which are insoluble and dark colored. The same conclusion was earlier published by Lortet and Hugounenq[9]; but Linck, on the contrary, maintains that the patina is due to a fine dust deposited by the winds, and adhering finally firmly to the surface, and that it comes from without, not from within the stone.[10] However this may be, surfaces cut away in making hieroglyphic inscriptions some 4,500 to 5,000 years ago, have in this long interval gathered but slight traces of this desert varnish. We must conclude therefore that its presence on the cut surfaces of the prehistoric cliff pictures, if it does not demonstrate, is at least in harmony with, a very remote date for the hunters who wrought these earliest records in the Nile valley.

As the flint implements still lying on the surface show us, these earliest Egyptian hunters were advancing to occupy more and more of the valley, as the waters of the river receded. When the Nile had finally sunk to its present bed, these prehistoric Nile dwellers settled upon its shores. Often they must have dwelt directly on the dry rubble heaps and stretches of sand and clay, which once formed the bed of the Pliocene Egyptian lake. Then the river began laying down the alluvial floor which has now covered the remains of these prehistoric settlements on the old lacustrine bed of the valley. There they lie with thirty feet of alluvium over them, and there it will be impossible ever to recover them.

Thus in the Fourth Glacial Period of Europe the Nile began to deposit the fertile alluvial floor which now forms Egypt (Fig. 7). As this floor gradually spread on each side of the river, it greatly improved the conditions under which the Nile dwellers lived, and while the hunters of Europe were contending with cold and ice, these men of northeastern Africa were enjoying a mild climate, of unequaled salubrity, and likewise

[8] "The Blackened Rocks of the Nile Cataracts," Survey Dept., Ministry of Finance, Cairo, 1905.

[9] "Coloration noire des rochers formants les cataractes du Nil," *Comptes rendus, Acad. Sci.,* Tome 134, 1902, p. 109.

[10] Linck, "Ueber die dunklen Rinden der Gesteine der Wuesten." *Jenaische Zeitschr. f. Naturwissensch.*, 35, 1900, pp. 329–336; quoted by Schweinfurth in *Zeitschr. f. Ethn.*, 35, 1903, p. 815.

freedom from the formidable mammals which confronted the European hunters.

Proof of the existence of these remote prehistoric settlements on the lower alluvium is not wanting, although it has thus far been found only in the general latitude of the southern apex of the delta. From 1851 to 1854 L. Horner sank ninety-five pits and borings down through the alluvium in this region.[11] "In a large majority of the excavations and borings, the sedi-

FIG. 17. PROSTRATE COLOSSAL PORTRAIT OF RAMSES II. AT MEMPHIS.

ment was found to contain, at various depths and frequently at the lowest, small fragments of burnt brick and of pottery." We know that burnt brick could not possibly have existed in the days of the dwellers on the lower alluvium, and Horner's "burnt brick" must therefore have been simply larger fragments of pottery. His shafts around the colossal statue of Ramses II. at Memphis (Fig. 17) disclosed the lower courses of the substructure supporting the statue. He also reached the bottom of the substructure under the obelisk of Sesostris I.

[11] See L. Horner, "An Account of some Recent Researches near Cairo, undertaken with the View of throwing Light upon the Geological History of the Alluvial Land of Egypt," *Philosophical Transactions of the Royal Society*, Vol. 145, 1855, pp. 105–138, and Vol. 148, 1858, pp. 53–92.

at Heliopolis. His measurements enable us to compute the rate at which the alluvium has accumulated in this latitude during the last three or four thousand years. Since about 1950 B.C. the rate of accumulation at the obelisk of Sesostris I. has been about 3.90 inches per century, while at the Memphite colossus of Ramses II., since the thirteenth century B.C., it has been about 4.08 inches. There is a slight margin of uncertainty due to our ignorance of the exact ancient level of the alluvium on the substructures and our ignorance of the exact dates of the monuments.[12] The borings in the latitude of the obelisk, but on the opposite side of the Nile brought up pottery from depths as great as fifty feet, or even nearly sixty feet. Using the rate of accumulation for the latitude of the obelisk, we gain a date of about 15,641 to 18,410 years before 1854 for the people of the lower alluvium. That is, the indications are that these earliest makers of pottery lived from 15,700 to 18,500 years ago.

Even larger figures than these would result from computations based on the discovery of pottery in the lower alluvium at a depth of 22 meters at the southern apex of the delta by Linant Bey; or at 27 meters on the Mahmudieh Canal by Abel.[13] On the Damietta branch in the delta Schweinfurth reports a human skull found at a depth of 24 meters.[14] It will be seen that the results of computation based upon such facts as these accord very well with Blanckenhorn's demonstration that the alluvium of Egypt began to be laid down long before the end of the last European glacial period, some eight or ten thousand years ago.

The earliest settlements on the old lake bottom and along the gradually widening strip of earliest alluvium have been deeply buried by the thick stratum of the upper alluvium which now floors the valley and covers the whole space between the river terraces (Fig. 18). There lies buried all that remains of the story of an advance through the possession of pottery, the gradually acquired ability to cultivate the wild grasses, the ancestors of our own cultivated cereals, and also the conquest of the wild life and its transformation into our domestic animals. The men who accomplished these things gradually reclaimed the jungles of the Nile rift, and as the valley then enjoyed but scanty rainfall, they began to cut the first trenches

[12] Horner's calculations of the rate are vitiated by the incorrect dates for the monuments themselves current in his day.

[13] DeMorgan, "Recherches sur les Origines," I., Paris, 1896, p. 19.

[14] In Blanckenhorn, "Geschichte des Nilstroms," *Zeitschr. der Gesell. für Erdkunde*, 1902, 761.

for the irrigation of their little fields, the predecessors of the irrigation canals which we survey from the top of the Great Pyramid. Thus these earliest Nile dwellers slowly shifted from the life of hunters to that of tillers of the soil and breeders of flocks and herds.

As generation followed generation it was found to absorb too much of the cultivable area to bury the dead in the alluvium. They therefore began to make their cemeteries just outside of the alluvium, along its margin. As the rising alluvium spread

FIG. 18. THE SURFACE OF THE PRESENT UPPER ALLUVIUM OF THE NILE VALLEY. Now covering the remains of the earliest human settlements on the floor of the rift or lake bottom,—as seen from the top of the Great Pyramid. (Photograph by Underwood & Underwood.)

out over the valley across the old lake bottom, these cemeteries were covered up in their turn. There can be little doubt that they stretch in a long wandering line, roughly parallel with the edge of the alluvium which now covers them. They are not below the limit of excavation—at least the later ones would be within reach of the excavator, if they could be located. Excavation would then be quite feasible. The problem of determining the location could be solved by boring, and this should be begun on a large scale all along the margin of the alluvium, in the endeavor to find a cemetery. A single cemetery

thus discovered might reveal to us the pottery, stone implements, probably cultivated grain and even domestic animals as well as the bones and skulls of an Egyptian community thousands of years older than any predynastic community now known to us. It would furnish us with a single mile post between the Egyptian whose stone implements we have found on the river terraces, or whose pottery has been disclosed by the borings already mentioned on the one hand, and on the other the prehistoric Egyptian in possession of grain, domestic animals and metal as we find him in the earliest cemeteries now known.

FIG. 19. A GROUP OF EARLY EGYPTIAN CEMETERIES ALONG THE RIVER TERRACE. Just outside the Margin of the Alluvium. (After Reisner, "Naga el-Der," pl. 20.)

The supposition that the cemeteries of the lower alluvial period were placed along the margin of the alluvium and just outside it, is based on good evidence. The earliest cemeteries known occupy this very position (Fig. 19). When they were first discovered about twenty-five years ago (1894–5), they suddenly revealed to us a group of pre-dynastic Egyptian communities, the earliest of which were already acquainted with metal (copper), though it was not yet plentifully used for implements. These cemeteries therefore represented an outgoing Neolithic stage. A quarter of a century of excavation among

these cemeteries has not yet carried us back into a pure Neolithic stage of culture. Must we therefore suppose that there never was any pure Neolithic culture in the Nile valley?—that the uninhabited Nile rift was invaded by outsiders already acquainted with metal?—and that for this reason the cemeteries of a metal-using people suddenly begin some centuries before 4000 B.C.? If we answer this question in the affirmative, we must assume the extinction or emigration of the pottery-makers disclosed by the borings in the lower alluvium. A population which had earlier maintained itself for many thousands of years along the Egyptian rift from the days of the plateau hunters, through their descent to the river terraces, until their occupancy of the lower alluvium and the discovery of pottery—after this enormously long occupation of the region—can not be conceived to have disappeared from northeastern Africa, leaving it uninhabited until some centuries before 4000 B.C.

It is consequently impossible to conclude that the pre-dynastic cemeteries begin suddenly and abruptly, marking the reappearance of man in the Nile rift after a period of thousands of years without any human inhabitants there. We must conclude, therefore, as we have done above, that the cemeteries which might reveal the successive earlier stages of a pure Neolithic, pre-metallic culture, bridging the present gap between the pottery-makers of the lower alluvium and the earliest pre-dynastic cemeteries now known, will be found under the present margins of the alluvium. Indeed my friend Mr. A. M. Lythgoe, of the Metropolitan Museum, while he expressed some reserve toward the above hypothesis when I proposed it to him, at the same time told me that he knew of one of the earlier cemeteries of which one edge was covered by the alluvium.

While there is a gap in our knowledge between the men of the lower alluvium revealed by the pottery of the borings and the men of the cemetery burials, it is evident that during the period represented by this gap the favored hunters of the Nile valley, not being exposed to the ice and cold of glaciated Europe, were able because of this sheltered situation in northeastern Africa, to advance so fast that they left far behind their Stone Age contemporaries all around the Mediterranean. This is shown at once in the quality of their stone implements, which had during this interval reached what we may call the Neolithic stage. The successive earlier stages represented by the flint artifacts at first left on the plateau and afterward on or embedded *in* the river terraces, while they were probably earlier than the Paleolithic implements of Europe, roughly correspond

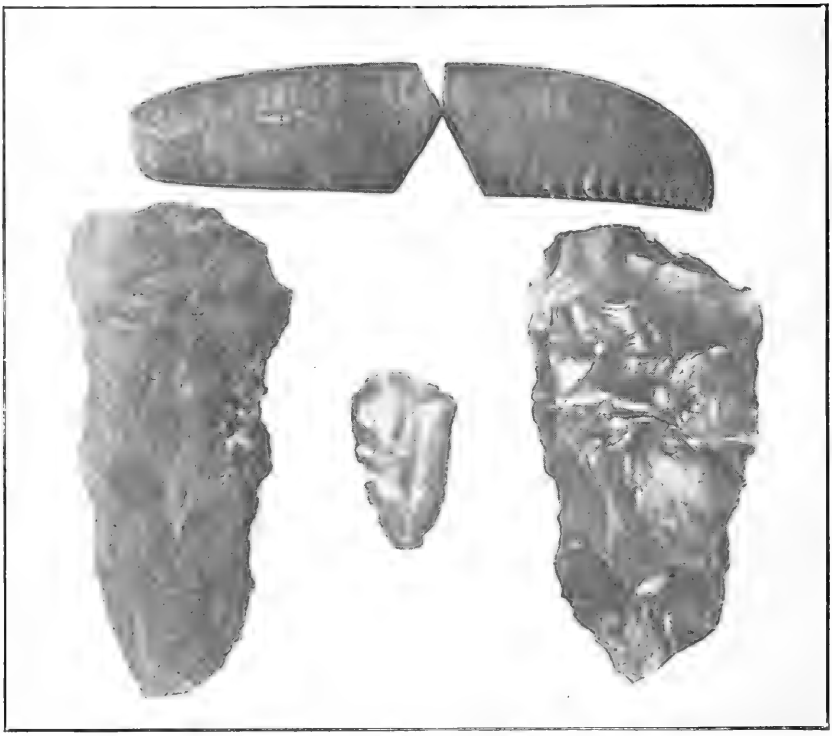


FIG. 20. THREE STAGES OF FLINT IMPLEMENTS FROM NORTHEAST AFRICA. The two below at right from the plateau; all three below are probably Palæolithic; the "ripple-flaked" knife above is from a pre-dynastic burial.

genetically to a Paleolithic stage of work (see lower artifacts in Fig. 20). The progress in the gap preceding the earliest cemeteries carried the Nile-dwellers forward to a Neolithic stage represented even in the earliest burials by superb "ripple-flaked" knives (see Figs. 20, 21). Nothing illustrates the superiority of the prehistoric Egyptian over all his contemporaries in other lands more conclusively than the remarkable precision, beauty and regularity of these flint knives. Nowhere in the world, indeed, have Neolithic craftsmen ever produced anything which can be compared with this work. This advance of Egypt demonstrates an industrial superiority over Europe and Asia beginning in the middle of the fifth millennium B.C., which was maintained some four thousand years and was never lost until the advance of Greek industry and commerce in the sixth century B.C.

The other leading craft possessed by these men of the earliest cemeteries was that of making pottery (Fig. 22), as we

might expect in view of the fact that their ancestors of the lower alluvium were already producing it. It contained a large proportion of Nile mud, and with its black-topped, red polished forms, or red polished with white line decoration and brown or black incised, this earliest cemetery ware is now well known.

It is impossible to offer here a complete inventory of the content of these earliest known burials in the Nile valley, but we may notice the presence of hand-bored stone vessels, face-paint palettes made of slate, and often bearing traces of the face-paint once ground upon them; besides many objects of ivory, like "figures, combs, hair pins, bracelets, rings, vessels, harpoons, etc."[15]

The people who thus equipped their dead lived in small settlements along the margin of the alluvium; for the presence of the cemetery of course means that a community of living people dwelt not far away in the cultivated area. A group of wattle huts furnished their dwellings, and around these stretched fields of barley, millet and wheat, with patches of flax, while grazing near were flocks of sheep and goats, and herds of long-horned cattle. Donkeys were already bearing the peasant's burdens from field to village, or village to market. The

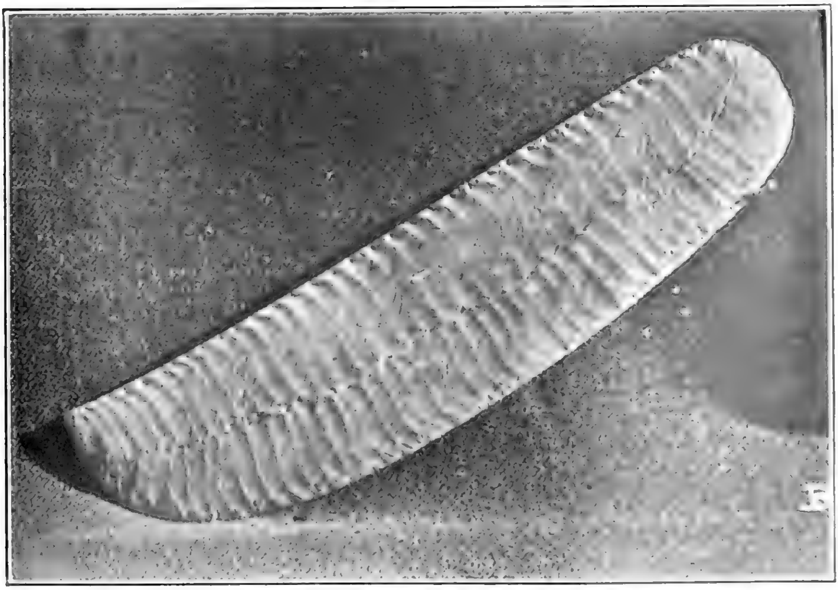


FIG. 21. FLINT KNIFE, RIPPLE-FLAKED ON ONE SIDE AND GROUND ON THE OTHER. From a burial in the pre-historic cemetery of Abadiyeh, Egypt. (Photograph by Petrie.)

[15] Reisner, "Archæological Survey of Nubia," Vol. I., p. 316.

great jungles and marshes which once stretched far along the valley, the home of the tropical beasts so long pursued by the plateau hunters and the men of the river terraces, had now been reclaimed and drained and made fit for cultivation of vegetable foods, or the pasturage of flocks and herds. A vast northeast African game preserve had thus been transformed from a jungle into the fertile home of the earliest cultivators of the soil and breeders of cattle and sheep anywhere known on earth. The settlements of these earliest agriculturists and cattlebreeders stretched far along the valley from lower Nubia[16] to the sea, and now these vanished generations, who originated animal husbandry and domesticated our food-grains still sleep in these cemeteries, scattered along the margin of the alluvium. Their villages have disappeared, but these cemeteries, discovered only twenty-five years ago, are great repositories of the life which once went on in the vanished settlements.

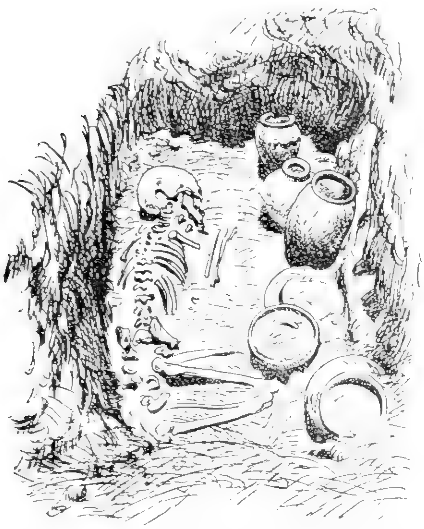


FIG. 22. POTTERY IN AN EARLY PREDYNASTIC BURIAL OF EGYPT. (After photograph by Reisner.)

The character of the food supply is revealed by an examination of the bodies from these cemeteries. The stomachs and alimentary tracts of practically all such bodies from the very earliest cemeteries contain husks of barley, while about ten per cent. also contain millet (*Panicum colonum*) of a species no longer cultivated. The husks of barley are much more difficult to detach from the kernel than those of wheat or emmer, the other prehistoric cultivated grains, and these latter, though they did not carry their husks with them into the bread, may also have been present in the bodies examined,[17] but do not happen to be represented by husks.

Emmer is a kind of split wheat (*Triticum dicoccum*), now very little cultivated. The wild form called by Koernicke and

[16] Reisner, "Archæological Survey of Nubia," Vol. I.

[17] See remarks of Netolitzky, to whom these researches were entrusted by Elliot Smith, in Hrozny, "Getreide," p. 178.

Aaronsohn *Triticum dicoccum dicoccoides* (better by Cook, *T. hermonis*), was discovered by Aaronsohn in 1906 on and around Mt. Hermon in north Palestine, and later as far south as Moab in the trans-Jordan country. In 1910 it was also discovered in western Persia on the Kermanshah road in the Zagros Mountains. There is no doubt, according to Koernicke, that we must recognize in wild emmer the ancestor of cultivated wheat. The

FIG. 23. BODY OF A WOMAN FROM A PREDYNASTIC BURIAL IN EGYPT. In the Field Museum of Natural History, Chicago.

cultivated form of emmer differs but slightly from the wild variety, and the development of our common varieties of wheat (*T. vulgare, turgidum,* etc.) must have consumed a long period of time, and required persistent practise of selection. Nevertheless, domestic wheat, with its long career of selective cultivation behind it, already appears in these earliest Egyptian communities, along with the little altered cultivated emmer.

It is interesting to notice that wild emmer is always found growing together with wild barley (*Hordeum spontaneum*), which is common in western Asia. The two were without doubt used together as food by early man, while they were still in a wild state, and domesticated together. Whether all this was done in western Asia or northeastern Africa can be determined with certainty, if ever, only when the botanical exploration of the Near East, at present hardly begun, shall have been thoroughly completed.

It should be noted that the grain found in the bodies of the prehistoric Egyptians and in the pottery jars accompanying them, dating back of 4000 B.C., is the oldest cultivated grain known to us, by over a thousand years. The nummulitic limestone crevices in which Aaronsohn found wild emmer growing in Palestine, are of course plentiful along the Nile, for such stone forms much of the material out of which the Nile terraces were built up. Here then, after using the wild barley and emmer seeds as food for ages, these early Nile dwellers may have begun to plant and cultivate them. It is only after ages of selective cultivation, as shown by the wheat, that the situation is revealed to us in these oldest cemeteries of the world. The long process of selective cultivation which had produced wheat before 4000 B.C., might therefore carry us back of 5000 B.C. for the beginning of the cultivation of grain, and the rise of agriculture.

It is also important to notice that such bodies as Fig. 23 often lie on a reed mat, with flaxen cord, and that some of them are wrapped in linen already displaying a good deal of textile skill. This is the oldest linen known to us, by an enormous margin. The fields of flax which furnished this linen represent a flax culture already very old, and descended probably from a time when the Nile dwellers originated the cultivation of flax.

(*To be continued.*)

MAN AND HIS NERVOUS SYSTEM IN THE WAR

BEING SOME REFLECTIONS UPON THE RELATION OF AN ORGANISM TO ITS ENVIRONMENT. IV

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The Onset of the Great War

The civilized world was startled in August, 1914, by the onslaught of the Teutonic hordes upon the people of Belgium and France. We had heard vague rumors of the gathering of the forces of war, and had heard the distant rattle of the saber at times. Some gifted individuals with a vision of the future had warned us, but we had not heard. We had seen the growth of autocratic power, but we forgot the principles of government worked out by our Anglo-Saxon ancestors, and we failed to appreciate the menace to the world of autocratic power at the head of a nation of millions of docile subjects. History was supposed to be one of the agents which would aid man in his process of muddling through by reminding him of past mistakes and the dangers of some unfortunate past experiences. But we heeded not the lessons of history, or did not know them. Some there were who cared not for history, and some said that the time spent on the study of history in our schools was wasted. In one sense, unfortunately, these latter may have been right, for few saw the approach of the storm before it broke. We were dazzled by the glamor of high organization and efficiency and we counted not the cost which must be paid for them. Like a storm, which, eluding the meteorological service, sweeps in from the sea, the war broke upon most of us without warning. But if we look backward, there are few elements in the present conflict that had not been the cause of uneasiness to statesmen and philosophers in the centuries that went before. Mention has already been made of the change in science, with the shifting from the basis of science for its own sake to the basis of work for practical ends. Some of us before the war noted the decadence in freshness and originality in the scientific thought of Germany, and were inclined to place its beginnings in the last decade of the nineteenth century. The extravagance of the imperialistic spirit, and the growing intimacy of the ruler and

the leading diety were made plain to the world in general. All these things had been noticed in Egypt and Babylon, and in both empires, they presaged disaster. The reaction of free peoples to the attempt to force such conditions upon the civilized world was similar to the reactions exhibited by other free peoples in other centuries when similar attempts were made to force such conditions on them. Man's internal organization shapes his behavior, and changes in internal organization come about only as the result of processes of evolution, most of which require great periods of time for their completion. Only in those countries whose peoples were decadent, or whose internal organization was such that individuality was not a matter of great importance, has the proper reaction failed to appear. But, although the combination of Teutonic ruler and leading deity loudly proclaimed the decadence of the peoples of the earth, such decadence either did not exist, or was confined to Germany. Judging from the lack of originality in Germany, individuality, aside from that manifested by the ruling combination, is not a matter of great consequence, and one would really look for a certain form of decadence there. The usual reaction occurred, and the Teutonic hordes were driven back.

But if we outside of Germany had not learned the lessons of the past, we were no worse than the denizens of Unter den Linden or Wilhelmstrasse, for assuredly they had not learned either. The Bourbon kings are not the only ones who "learned nothing and forgot nothing." The Hohenzollerns had not learned that virile races resent attempts on the part of the ruler and leading deity of an enemy country to suppress the expression of their individuality. They had not forgotten the traditions of the Egyptian and Babylonian kings. Their failure, either to learn or to forget, has brought disaster to them as well as to us, and we most unselfishly hope that theirs will be the greater disaster.

The Change in German Ideals

Strangely enough, one of the most beautiful expressions of the biological ideal of life as I see it comes from the nation in which, in the immediate past, the world has witnessed a recrudescence of monarchical absolutism as rigid as that of Assyria or Babylonia. As Goethe stated it:

> Wie das Gestirne,
> Ohne Hast, ohne Rast,
> Drehe sich jeder
> Um die Eigene Last.

But in Germany of the last decade there were few indeed who could draw each one toward his own goal. The recent ruling house of Prussia whose ancestors five hundred years age were in "Hide and Hair" (perhaps because of his myopia Treitschke was unable to see the cloven hoof, or because of his deafness was unable to hear the clatter) had not only arrogated to itself the privilege of regulating the destinies of all individuals in the German Empire, but had also expressed the desire to extend the same beneficent protection to the individuals of the world in general. But the world in general has long assumed this to be the prerogative of a Being of much greater historical antiquity and, as we have been wont to believe, vastly greater ability than any member of the Prussian ruling house who has yet appeared. To meet this objection, the Kaiser has announced that the welfare of the world has been expressly delegated to his care while his immediate superior is looking after the rest of the universe. To some of us, the credentials which the Kaiser presented are in the same class with other German state documents—mere scraps of paper. There is one point on which the Kaiser may claim a biblical resemblance,—"I came not to send peace upon earth but a sword." One point of resemblance is not, however, sufficient to establish the identity of the species of two individuals, and few other points of resemblance occur to me at this moment. But granting all that even the most charitably inclined person could grant, that the Kaiser is not a sufficiently competent systematist to be sure of his identification, and that this delegation of power really comes from the German tribal deity, I still confess to lingering doubt whether the Kaiser is strictly correct in his idea of the geographical location of the dwelling place of this tribal deity. To my mind the geographical range assigned is incorrect, for it partakes much less of the nature of a creature of light than a being of darkness.

The mistake of the German war lords is as patent to the biologist as to the politician or the statesman. If I interpret the course of organic evolution correctly, it has made of man's brain, and through it his mind, a force of nature. There have been occasional lightning flashes of genius in the course of history, and some cataclysms in the form of revolutions, but, on the whole, its action has been more like that of other forces of nature which first cut deep valleys in a newly elevated tableland, then widen the valleys, disintegrate the rocks and reduce them to fine particles, and transport them to other regions until only the hills remain. Finally the hills are leveled and the

genial plain is open to view. So, century after century, man has been making assaults upon the strongholds of absolutism until, in all the civilized world, there is now, let us hope, not one flagrant remnant. The holders of the castle would come forth to dominate the earth, but their vision of a subjugated earth is not to be realized. Not even their shining swords could cope with a force of nature, but fools that they were, they knew not what they would do.

The Problems of the Post-Bellum Period

The problems arising out of the war are not settled by the mere cessation of hostilities. The problems of reconstruction demand solution, and upon the wisdom of their solution hangs the destiny of millions of people for years to come. Some comments on these may be permissible here.

I have written of the struggle of man against conventions which repressed the expression of his individuality. Perhaps some may infer that I would do away with all restraint, but against such an inference I would utter a protest. There are good biological reasons why all restraint should not be removed, and one might argue that certain other forms of restraint should be added. In fact, I believe that some additional restraint may be placed upon some tendencies in human nature.

The effort of the Kaiser and the war lords of Germany to impose their will upon others may be regarded as a form of behavior shaped by their internal organization, and, hence, as an effort to express their particular type of individuality. That such efforts should be restrained, few outside of the Teutonic empires or not of Teutonic ancestry will doubt. The war was the immediate effort to restrain such tendencies, but wars do not last forever, and the duration as well as the security of peace will depend upon what means of restraint is adopted after the war. A change in internal organization might be one solution of the difficulty, but I am not sanguine that this can be effected. The student of animal nutrition, regarding the animal as a chemical mechanism, recognizes that, from the dietary point of view, "the internal organization of an animal is not accessible to improvement."[10] Having settled this point, he must do the best he can with whatever foodstuffs may be available. Although, as I have emphasized in these pages, the organization of the higher portions of man's nervous system is not as rigid as that of the chemical mechanisms of the body, I

[10] Armsby, "The Conservation of Food Energy," Philadelphia, 1918, p. 26.

still think it the part of wisdom not to assume that any great changes in reaction will occur, but to assume that, because of an internal organization which one can not greatly change, the reactions will not tend to change greatly.[11]

Having made such an assumption, we should select such remedies as will best suit the conditions. Anglo-Saxon races in general have tried to permit the manifestation of individuality on the part of the citizens of the state by limiting on the one hand, the power of the state to interfere, and on the other hand, providing lawful means of restraint for such persons as failed to recognize or to heed the restraints imposed by reason. There is no known way of preventing a ruler from becoming mad, but ways may be devised for preventing him from exerting unlimited and unchecked power during his madness. When a whole race becomes mad, forcible restraint becomes necessary, but, if left to itself, there is little chance that a whole race will ever become mad. But if the race is to be trusted, the power of a mad ruler to sway them must be curbed. One mad individual can do but infinitesimal harm alone compared to the harm he may do when he retains unchecked control of a whole people in his madness. But happily the effort of the War Lord of Potsdam to impose his own kind of convention upon the peoples of the world has turned out to be simply another illustration of the vanity of human ambition.

Despite the comments of philosophers on the vanity of human ambition, there is little fear, or hope, that it will fail among the children of men. And the prudent children of men will seek ways whereby the ambitious one may be prevented from injuring his fellows. The establishment of democratic forms of government has done much to remove the menace of political and military ambition, but other forms of civil ambition have grown up since the days of the Magna Charta, the control of which has not yet been satisfactorily worked out. It would seem to a mere civilian that the same principles which led our Anglo-Saxon ancestors to limit the power of one man

[11] If the conviction expressed in the text be well founded, then, broadly speaking, *as his neurones are, so the man is.* In this sense Goethe's words, in the mouth of Mephistopheles, can be made to bear a new and almost prophetic significance:

> Du bist am Ende—was Du bist.
> Setz Dir Perrücken auf Millionen Locken,
> Setz Deinen Fuss auf ellenhohe Socken,
> Du bleibst doch immer, was Du bist.

Barker, L. F., "The Nervous System and Its Constituent Neurones," p. 221, New York, 1899.

or small group of men in a political way might be extended to all other forms of human activity.

As a biologist, I would emphasize the vast possibilities for evil of a trained or highly organized group of men in the higher stages of society. Without organization and propaganda, ideas make their way but slowly, and only after long discussion. The glamor of organization and efficiency have appealed to us strongly, and we have allowed the formation of great and powerful organizations which are in control of machinery for extensive and widespread propaganda. Many of them have the avowed intention of forcing their own particular types of convention upon great numbers of people. Many of them have expressed the best intentions and have done no great harm as yet. Others have already shown evidences of sinister designs. Many were patterned after similar organizations with strong centralized power. It will be well for us if we recognize these possibilities early rather than late.

The German idea has permeated our universities more than some of us would wish. German universities became a part of the machinery for imperialistic propaganda, and a grateful government has, in turn, established machinery for propaganda for the use of the universities. We have been so harangued and shrieked at by German men of science that, without machinery for propaganda, ideas originating in other countries or ideas opposed to those made in Germany had small chance of meeting with the calm, dispassionate consideration which scientific questions demand, and without which opinion in science becomes but little more than a mere manifestation of mob psychology. Prussian ways of getting professorships, Prussian methods of control once the professorship is obtained, and the will to power rather than disinterested scholarship and service, while by no means universal or universally commended, have been too frequent in American universities to conduce to perfect equanimity on the part of those who believe in democratic principles of merit and justice. It was with these things in mind that a friend expressed in 1914 the hope that one result of the war would be that our universities would become less Prussianized.

Teutonic influence has extended still farther into academic affairs in America. Impressed by the 42-centimeter Busy Berthas and the potency of poisonous gases in warfare, which have been the fruits of the application of German science to the practical affairs of life, there has been much agitation in university and some other educational circles for the extension of

practical education and the restriction or suppression of other forms of academic activity. Practical knowledge is necessary for some of the practical affairs of life, and no one would deny its value. But the argument that we must do certain things because they have been done in Germany leads one to inquire whether the results will be the same here as in Germany. Until some assurance is forthcoming on this point, I am not willing to sacrifice any or all independent opinion of my own merely for the sake of imitating Germany. And I would like further assurance that study of a non-practical sort is without value to the world in general. One might go even farther than this and ask for assurance that work of a non-practical nature is actually harmful to the world. For the scholar works out those things which express his own individuality, and the attempt to restrict such a means of expression is similar in its nature to other attempts to impose restraint upon individuality by setting up an arbitrary convention.

We have forgotten, however, some other things in Germany when we focus our attention upon merely practical matters of their educational system. Art has flourished in Germany in times past and their galleries have been enriched by fair means or foul by great works from other countries. Long ago Huxley called attention to some of the defects of a purely "practical education" and it may be well to recall his words now, for I believe that they are worthy of serious consideration to-day.

> The mental power which will be of most importance in your daily life will be the power of seeing things as they are without regard to authority; and of drawing accurate general conclusions from particular facts. But at school and at college you shall know of no source of truth but authority; not exercise your reasoning faculty upon anything but deduction from that which is laid down by authority.
>
> You will have to weary your soul with work, and many a time eat your bread in sorrow and in bitterness, and you shall not have learned to take refuge in the great source of pleasure without alloy, the serene resting place for worn human nature—the world of art.

Practical matters or science or applied science have engaged men's attention in the days of the war, and there are some, even many, who fear that the scholar who works not toward practical ends alone will disappear in the process of reconstruction after the war. But idealism has survived in the world too long to disappear now. For if, by any mischance, the scholar should be driven from our universities and be supplanted by merely practical men, somewhere in the world he will find refuge. We may, in the last extremity, go part way back to the conditions of the scholar in Paris in the fifteenth century as Victor Hugo describes them:

> The Ville contained the Halles, the City the Hotel Dieu, and the University the Pre aux Clercs. For offences committed by the students on the left bank (of the Seine), in their pre aux Clercs, they were tried at the Palace of Justice in the Island, and punished on the right bank at Montfaucon, unless the rector, finding the University strong and the king weak, chose to interfere; for it was the privilege of the scholars to be hanged in their own quarters.[12]

There is small hope that all his former privileges will be restored in their entirety unless liberal legislatures amend the charters of our universities so as to allow the erection of their own gallows, but somewhere or somehow the scholar will claim and receive some of his ancient privileges even among the practical men of the day. Perhaps those universities which have established schools of electrical engineering might substitute the electric chair for the ancient gibbet. Garrets may again come into style, and hermitages in the forest may again shelter him from the elements, but the scholar will and must work. But the value of idealism for the world is not yet passed. Surely it is safer for the world that the pale student should spend his time in deciphering the tattered fragments of a Greek palimpsest than that he spend his time in devising a new poison wherewith to slay his fellow man. It is safer for the world that an astronomer should spend his time calculating the motions of a distant sun than that he should calculate the path of a projectile that will kill women in a church seventy miles away. It is better that a man lose his life in vain searching for the pole than that he save it in dreaming of "Weltmacht oder Niedergang," unless he achieves Niedergang. It is better for the world that our children should see great works of art, or great collections in museums than that they grow up on a diet of blood and iron. It is better that one should penetrate to the nethermost parts of the earth and brave the danger of beasts of prey or disease-bearing insects than that he should dream of feats of arms in a war of conquest. For high enterprise and romance are not dead in the world and the history of science itself is "the history of an adventure." But the scholar sets not out on his adventure deliberately to slay.

While the idealist may dream of the day when restraint shall no longer be necessary among the children of men, those who pay attention to the facts of biology must recognize that restraint is still necessary. It is not within the province of the biologist to impose this restraint. That task falls to the lawmaker, with whom the biologist has seldom maintained intimate

[12] "Notre Dame," Book III., Chap. II.

personal relations. Yet the problem of the lawmaker and the problem of the biologist have some elements in common.

The methods of science and of law have certain elements in common, although attention is usually focused on their differences rather than on their resemblance. The practise of law consists in the application by deductive reasoning of the principles of law to particular cases. The actual practise of science lies more in the accumulation of facts from which we may one day arrive at a general principle through a process of induction. Yet law must have its inductive side, for the great jurists of the world have built up its principles, which lesser men may apply. And when the great scientist has built up his induction from the facts accumulated by many lesser men, application to particular cases by deductive reasoning is a legitimate method of science (Thomas Case). The man of science has sometimes commented on the waste of human energy resulting from the obscurity of some of the forms of law and the technicalities of its administration.[13] But just as the man of science recognizes the difficulty of arriving at a clear, definite and unequivocal statement of an induction from the facts at his disposal, so the clear-minded man of law recognizes the difficulty of making a clear, definite and unequivocal statement of a legal principle. But the man of science recognizes that the inductions of science must be revised from time to time, or even wholly rejected, as the number of facts increases and their relationships are more carefully studied. The man of law sometimes insists on the retention of his venerable forms and attempts to fit all modern conditions to an old generalization. The body of law is apt to become a rigid convention and, although the motives of its founders were without reproach, to become an impediment to progress. I have called attention elsewhere to the fact that previous attempts to settle international disputes in accordance with the terms of existing convention have not been wholly successful in avoiding subsequent disagreements or in preventing later wars.[14]

The peace conference which is to meet to settle the late war will be faced with the task of arriving at certain principles for the guidance of nations. Those principles, whatever they may be, must be arrived at by a process of inductive reasoning. For the peace and security of future generations, let us hope that the final decision of this conference will be in accordance with the facts as they are known to-day, and that the attempts

[13] Bagehot, "Physics and Politics."

[14] Pike, *The New York Times*, 1917.

to impose restraint upon generations to come by the retention of outworn and biologically vicious convention will fail. For unless coming generations are decadent, they will refuse to be bound by arbitrary convention and the struggle will break out anew.

The view that individuality is a product of a result of evolution which I have arrived at is not particularly new. But it needs to be kept before us. Bergson's statement has already been quoted. It seems worth while to give here a statement by an American psychologist and philosopher with a more distinct political bearing:

> The practical consequence of such a philosophy (*i. e.*, the philosophy of looking for the significant things in the lives of others), is the well-known democratic respect for the sacredness of individuality, is, at any rate, the outward tolerance of whatever is not itself intolerant.
>
> These phrases are so familiar that they sound now rather dead in our ears. Once they had a passionate inner meaning. Such a passionate inner meaning they may easily acquire again if the pretensions of our nation to inflict its own inner ideals and institutions *vi et armis* upon Orientals should meet with a resistance as obdurate as so far it has been gallant and spirited. Religiously and philosophically, our ancient doctrine of live and let live may prove to have a far deeper meaning than our people seem to imagine it to possess.[15]

In the interest of stability of our American institutions, it is to be hoped that the attempt of a European nation to inflict its own inner ideals and institutions *vi et armis* upon other nations and ourselves may act quite as effectively as James hoped the resistance of the Orientals to our own attempts would in imparting a passionate inner meaning to the phrases that sounded so dead five years ago. Let us hope also that the deeper meaning of our ancient doctrine of live and let live may come to us without further unhappy experience. For, as I believe, certain forms of propaganda in our country are not far removed in spirit from militarism, and neither is far from intolerance.

As for our failure to appreciate the teaching of history, another sentence of James is pertinent here: "The changing conditions of history touch only the surface of the show."[16]

History to most of us is a matter of the distance receptors alone, and may have no significance for us. It is only when things touch us more closely, when they become matters of the contact receptors, the proprioceptors and the interoceptors that they have real significance to us and awaken a real human in-

[15] James, William, from the preface to "Talks to Teachers and Students," New York, 1900.

[16] *Ibid.*, p. 300.

terest. The Egyptians and Babylonians were too far away for anything but the distance receptors to reach them, and we did not translate our impressions from sight and hearing into the terms of impressions from other sense organs. The present war should have touched us deeply enough, and should have made sufficient appeal to those receptors which apprise us of pain and sweat and hunger to give history a real meaning among us for generations to come.

History, from one point of view, has a distinct interest to the biologist. The intrigues of rulers and the salacious details of the private life of court personages does not necessarily impress him. But the reaction of a people to any given set of social or political conditions may have a more intimate relation to the work of the naturalist. For just as the testimony of the rocks, the paleontological history of animals, shows what course the evolution of form has followed in the race, so we may regard the record of history as showing what man has done under a given set of conditions which, in more ways than one, bear a resemblance to some of the experimental conditions which we sometimes impose in order to study the behavior or reactions of animals.

A quarter of a century before James wrote, the memory of the events of our Civil War was still vivid enough to lend significance to the facts of history. To quote again from Lowell:

> They steered by stars the elder shipmen knew,
> And laid their courses where the currents draw
> Of ancient wisdom channeled deep in law,
> The undaunted few
> Who changed the Old World for the New,
> And more devoutly prized
> Than all perfection theorized
> The more imperfect that had roots and grew.

If in so short a span as one generation we shall again forget the stars the elder shipmen knew, and in the space of half a century be again involved in a struggle for our existence as free men, let us hope that we will not fail. Wars will probably not cease because attempts at aggression will end, but if wars do cease, it will more likely be because we learn to recognize early the signs of danger, and deal with the agents of evil before they become too powerful to be controlled. Before we become able to do this as a nation, we must recognize the value of "The more imperfect thing that had roots and grew" as compared with the schemes for universal salvation that are being so generously set before us in these later days. We may

vaguely wonder whether the doctrine of "America über Alles," unashamed and unrebuked, will be wholly an influence for good.

I have attempted to show that the Prussian government of to-day has in it much of the elements of the old tribal theocracies. I have attempted to show also that man's mind which, if I am right, is a product of his evolution, rebels against any such scheme of government. To the biologist such a system is merely the recrudescence or the persistence of superstition. I have attempted to point out also some of the dangers of such a scheme. But these dangers have been so well summed up and so trenchantly expressed by a philosopher that I quote them in closing. Few in his day appreciated their significance, and many and bitter were the attacks upon the author at the time, but the application to the Prussia of the past two decades seems clear. To those who would save such a system as the Prussian autocracy the words may be particularly dedicated: "That which you keep in your hearts, my brothers, is the slender remnant of a system which has made its red mark on history, and still lives to threaten mankind. The grotesque forms of its intellectual belief have survived the discredit of its moral teaching. Of this what the kings could bear with, the nations have cut down; and what the nations left, the right heart of man by man revolts against day by day. You have stretched out your hands to save the dregs of the sifted sediment of a residuum. Take heed lest you have given soil and shelter to the seed of that awful plague which has destroyed two civilizations and but barely failed to slay such promise of good as is now struggling to live among men."[17]

[17] W. Kingdon Clifford, "The Unseen Universe," London, 1879.

APPLIED NUTRITION FOR RAISING THE STANDARD OF CHILD VITALITY

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WHILE approaching the brink of the dawn of a world cataclysm that catalyzed evolutionary progress in both humane and inhumane activities, let us take inventory of a phase fundamental in world domism—the "reconstruction" problem of child welfare.

The war has sobered us and its lessons must be taken truly to heart for our sufferings were our instructors, Pathemata Mathemata. Of the doctrines reaped, two point for our consideration—(1) the necessity for physical and mental efficiency in every citizen and (2) the menace of the dearth of youth.

Ours is the great obligation to build the rising generation an optimum in body, mind and character if we are to carry into the future the strength and steadfastness which mark the present. Sentiment and emotion alone eventually fade into oblivion —the deadly policy of laisser faire, laisser passer. They must be translated into practical terms of concentrated effort and endeavor; now is the time. Let nothing mar nor hinder, not even the blood-coagulating dollar. The time is here, the place is everywhere and the obligation every one's to serve in the cause of national upbuilding through child welfare, for the child is the embryo of the nation's progress, the parent of the future generation, the potential citizen.

THE ANTECEDENT FACTORS OF THE RESULTING CHILD

The caliber of the child may be expressed as the resultant of the two "moments," heredity, the intrinsic organization of the germ cells and environment, the extrinsic, stimulating, inhibiting or modifying influences. Evidently to attain the ideal child

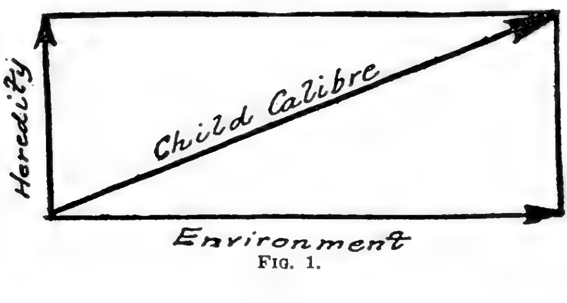

FIG. 1.

these two causative factors must be ideal. Modern applied scientific tendencies have been in the direction of "patching-up" the child rather than in the more important or at least as important fields of heredity and environment perfection. There is nothing against these tendencies except that they are unbalanced. To raise the health standard of the average child we need science in the service of alleviating the ill-causes much more so than remedying the ill-effects.

Let us throw the balance in the other—the more serviceable direction. Curing superficial symptoms of woeful causative inadequacies has never and will never relieve the situation. We need to face and cure both evils equally to serve as we should and as we can with intelligent application of our available knowledge. The application of the sciences on child welfare

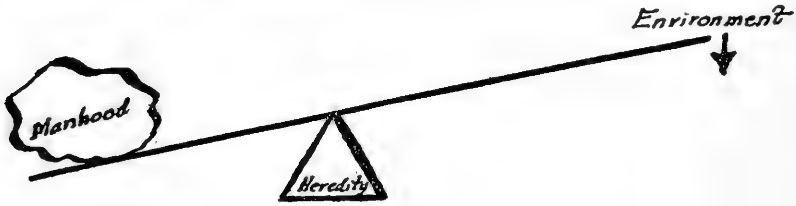

FIG. 2.

have thus far been delinquent and the more that "one-sidedness" is practised the longer the prolongation of our low heredity status to our own detriment and that of the coming generations upon which the nation's future depends. Of the two causative factors in child molding—heredity and environment—the latter promises far more effective returns per unit effort, but both are in dire need of attention.

For our immediate purpose let us consider environment and its component influences of which the home and the school are the most permeating. The salvation of the child lies in the complete harmony of school and home functioning with the body developments of the child with age.

CHILDHOOD IN CONSTANT FLUX AND REFLUX

An analysis of body developments with age shows the child not a miniature man, but distinctly different from the adult in vitality, intellect, emotion, instinct and metabolism. As a matter of fact, these intrinsic differences are characterized throughout childhood by their constant alternation in activity and passivity. Child metamorphosis proceeds with constant flux and reflux—a living illustration of Newton's Third Law of Motion: "Action $\rightleftharpoons$ Reaction."

PERIODICITY OF ACTION AND REACTION IN HUMAN METAMORPHOSIS

Age	Growth	Coordination	Development	Characteristics			
Birth to 7	Rapid	Motor	Corporeal	Endo-thermic	Recep-tivity	Stimu-lation	Exalta-tion
7–14	Slow	Motion and emotion	Intellec-tual	Exo-thermic	Produc-tivity	Fatigue	Depres-sion
14–17	Sudden		Corporeal	Endo-thermic	Recep-tivity	Stimu-lation	Exalta-tion
18–25	Slow	Emotions and ideals	Intellec-tual	Exo-thermic	Produc-tivity	Fatigue	Depres-sion

THE RELATIONS OF SCHOOL LIFE TO THE CRITICAL TRANSITION EPOCHS IN CHILD DEVELOPMENT

In the light of the above analysis of human metamorphosis the school's responsibility in molding childhood in harmony with its fluxating development is evident. Thanks to the world educators and psychologists for stimulating research in the cause, but as yet our school systems are far from what they should and could be.

The effects of school life upon the child are appalling. Extensive surveys throughout the country have shown persistent prevalence among school children of: (1) growth retardation, (2) appetite deterioration, (3) corpuscle degeneration, (4) blood deoxygenation, (5) metabolic alterations, (6) superficial respiration, (7) morbidity, (8) malnutrition, (9) remediable defects, (10) reduced vitality. Is the school functioning harmoniously with the development periods of the child? Is the home guilty of negligent depreciation of vitality through inadequate nurture, health conditions and care? Yes, the school and the home are the reciprocally responsible sources.

The scope of the educational machinery is still narrow if its aims are not generally all-inclusive and well-balanced, if its habitual training for healthy physique is not on par with the mental. The great problem at our advanced stage is to get away from an education for a living to an education for a life to best enable and set free each individual to do his and her best for the common welfare. Upon that necessary and sufficient transition in educational ideals pends the safeguarding, upbuilding and perpetuating of our American democracy.

Then too the "rule-of-thumb" empiricism for bringing up children is incompatible with their variant needs. Deficiencies heaping up thereby as a result of neglect and ignorance among poor and rich alike rob humanity of latent productivity—a great impediment upon our nation, an irretrievable waste of our rising generation. The scientific and rational principles of health and nutrition must become more assimilated into the con-

ceptions and practises of the public or even the medical profession if we are to build a maximum efficient democracy.

Applied Nutrition for Raising the Standard of Child Vitality

With the vast number of variegated food materials, natural and artificial, palatable and adulterated, drugged and normal all behind attractive camouflaged labels it behooves one to select what will constitute an adequate diet for the growing child. Faulty diets have been devitalizing the innocent child with resultant deficiency diseases. Malnutrition has impoverished the child world with reduced vitality, disease susceptibility, minimized educational receptivity, anæmified physique and resultant stunting of mental and physical development—basic elements for mollycoddles not men, wishbones not backbones, jellyfish not brains. The retribution for dietetic sins in childhood is a much more speedy reaction than in adult age. Stop the starving, stunting, stultifying of the child. It's criminal. Every child has a biologic birthright to a useful body and mind. Grant that right by complying with natural laws governing body needs formulated by science. The science of nutrition is at our service.

Instinct a Non-reliable Guide in Food-selection.—The perpetuity of change in the human species modifies simultaneously the dependent factors on health preservation as a result of the curtailment of the activities of various parts of the body so that claiming practicability of instinct as a natural guide on the basis of past service to humanity is irrelevant. Furthermore, instinct varies with personal idiosyncrasy, habits, conventions, moods—conditions not necessarily compatible with food value to the body. Reliable knowledge should be if it is not at the command of all to supplant inherited instincts.

From Birth

(Relative in proportion to body weight)

Increase	*Decrease*
1. Density of blood.	1. Water in blood.
2. Concentrated red corpuscles.	2. Concentrated white corpuscles.
3. Concentrated haemoglobin.	3. Iron content.
4. Mineral matter.	4. Organic Matter.
5. Calcium carbonate.	5. Calcium phosphate.
6. Oxygen absorption.	6. Thyroid gland, kidneys, thymus.
7. CO_2 excretion.	7. Suprarenal capsules.
8. Colloidal substances.	
9. Brain, heart, lungs.	
10. Metabolic intensity.	

The Child Needs (1) tissue foods, (2) energy foods, (3) regulating foods, (4) protective foods. Nutritional instruction should be on the basis of food function rather than composition of interest to the chemist only since the former appeals to the pupil's actual experience and familiarity while the latter rarely strikes "home."

The general factors interrelated with child nutrition are a knowledge of (1) food functions in body, (2) essential body component sources in foods, (3) relative amounts of food required per age, (4) adaptable foods to the digestive system, rate of growth, state of development, (5) feeding intervals per age, (6) proper sequence at mealtime.

The Tissue Foods

Feeding children involves not only waste repair, the adult need, but new tissue building as well if the child's growth is not to be stunted. The body tissues are: (1) The circulating—blood, (2) the master—brain and nervous system, (3) the contractile—muscles, (4) the supporting—bones and teeth, (5) the cryptorrhetic—thyroid and secretions.

A diet may contain all the necessary constituents for tissue repair and yet may be lacking in some constituents essential for new tissue growth. If these constituents can not be formed in the child organisms as they can in the adult out of others in the diet, it is evident that they must be supplied to the child from without else abide by the fate of inadequate dieting. The animal and vegetable complex proteins upon the action of proteolytic enzymes in the stomach are ultimately hydrolyzed into the digestion products essentially the various amino-acids. These, absorbed into the blood, are the building units of the body tissues to be formed. Since different protein foods contain not all of the amino-acids essential for tissue synthesis and in different proportions, it is very essential that the child get a proper combination of proteins for the body availability of all the amino-acids and their right proportions required for both new tissue building as well as for tissue repair. It is not strictly protein as such, but amino-acids that the body needs. Those indispensable to growth are arginin, cystin, histidin, lisin, and those essential to maintenance or tissue repair are the aromatic amino-acids. Any surplus is partly converted by de-amination into carbohydrate and fat to contribute to the body's energy requirements. In all the child's total protein requirement is more per unit body weight than the adult's. This does not mean, as is the usual misapprehension, that the proportion of proteins to

total food intake is greater. The normal need is protein to be ten per cent. of the total ration for children as well as for adults. The necessary and sufficient protein utilization and assimilation depend on what may be termed the *amino-acid efficiency* of the ingested food. From this standpoint a few foods may be graded as follows: (1) milk, eggs, cheese, meat, fish; (2) wheat, oats, pulses, nuts; (3) corn; (4) gelatin. This does not mean that only those in (1) should be consumed, for the others may have essential components for other body functions. It does point, however, to the necessity for guarding children's diet so that upon digestion the specific kinds and proportions of amino-acids will be available.

In infant feeding the available chemical components of foods are not the only factors, but their physiologic functions must be considered as well. During the nursing period the infant is not adapted for the metabolism of nutrients derived from sources other than woman's milk. Breast feeding develops the digestive tract, functions in better brain and nerve building by the lecithin content in the milk, gives all the amino-acids in the proportions requisite for growth, serves for stronger teeth and is generally correlated with higher mortality. Furthermore, *B. bifidus* is present to the exclusion of other forms in the normal breast-fed child. It produces no putrefaction, decomposes no albuminous matter which would form toxic products. These bacilli are more than harmless, they are an important defense in preventing intestinal putrefaction and displacing harmful flora.

The Energy Foods

Children's energy requirement is greater per unit surface area of the body than the adult's because of their higher metabolism. *The energy functions* for keeping body temperature normal, for the maintenance of the life processes more rapid than in adult, for muscular activity, for body syntheses of the building materials utilized in repair and growth, and for storage.

The carbohydrates are absorbed into the blood plasma as monosaccharides after intestinal digestion. These upon oxidation liberate energy for the performance of muscular movements as well as for bringing about endothermal reactions. Any surplus is stored in the liver, muscles and other organs as glycogen. Excessive amounts beyond the normal assimilation limit of the organs tend to be transformed into fat.

Fat, the concentrated potential energy source, after being

hydrolyzed in the stomach yields fatty acids and glycerol which are absorbed by the lymph vessels and together taken up by the blood plasma, distributed to the tissues according to their needs, contributing to the constitution of protoplasm as well as for heat production. Any excess aids the conservation of body heat.

Any excess protein intake will be de-aminized, yielding carbohydrates and probably fats for the body's energy requirements. In other words all foods are sources for heat and muscular movements in proportion to body preference, specific nutrient availability and surplus.

In child development the specificity of carbohydrate function is prevalent. Galactose, for instance, is essential for nerve medullation of the cerebrum. It is derived from lactose, the milk sugar and none other will replace it. Again, milk, although containing an insufficiency of the total carbohydrate requirement, has the essential sugars entering into the composition of the child's body. Another favorable point is that lactose in milk is least liable to fermentation, whereas all other sugars yield acid products in the stomach.

Sugar is a beneficial muscle food for the children if taken in diluted form. Excessively large concentrated amounts of sugar ingested irritate the tissue, abnormally increase the mucous secretion as well as the acid gastric juice content, thereby interfering with normal digestion. Furthermore, the requisite vegetable food intake will be diminished since it satisfies the appetite without adequate nourishment with serious consequences of the deficiency diet to growing children.

The four per cent. fat content in milk in the emulsified palatable and easily digested form is the optimum satisfying the caloric need of the normal child. Excessive fat ingestion overtaxes the infant's undeveloped digestive system, causing the prevalent gastrointestinal indigestion with a simultaneous loss of alkalinity which may result in acidosis.

The Regulating Foods.

During the functional activity of the child mineral nutrients are indispensable for all tissue building providing the supporting structures as well as for metabolic regulation. Among the diverse functions of the inorganic components in the body are:

A. As Stimulators—
- *a.* Conducting nerve impulses.
- *b.* Activating enzymic transformations.
- *c.* Increasing metabolic reaction velocity.
- *d.* Catalyzing cellular activity.

B. As Regulators—
- *a.* Controlling heart and muscular activity.
- *b.* Maintaining blood acid-base equilibrium.
- *c.* Counteracting harmful products by chemical combination.
- *d.* Governing respiration processes.
- *e.* Aiding proper membrane permeability.
- *f.* Providing a solution concentration of normal osmotic pressure.

The prevalence of anemia during the weaning period of the infant is due to iron inadequacy, which causes a diminution in the hemoglobin and chromatin bodies, both largely responsible for metabolic and growth processes. It is imperative that special provision be made in the child's diet for an iron content sufficient for both body maintenance and increasing blood supply, since the iron reserve continually diminishes from birth on. The iron component in the daily ration should not be the sport of chance, but purposeful inclusion if due justice is to be afforded to the child's development. Medicinal inorganic iron in tonics is not only a costly substitute for a healthy dietary violation, but no actual substitute at all since it is temporary acting as a stimulus rather than a hemoglobin producer. You can not beat nature to it, but accept her organic iron in foods combined in assimilable form for the body.

Malnutrition associated with flabbiness, weak bones and teeth are a direct result of phosphorus deficiency. Retarded development, structural weakness and rickets observed in children are effects of calcium inadequacy. The structural supporting tissues partake of the continuous metabolic changes as well as the others. The former need continual replenishment as well as the latter. The child's need in addition to the normal calcium and phosphorus assimilation in all tissues is a sufficiency for the constant structural increase during growth.

Children must have an adequate supply of inorganic components. As a matter of fact maximum duration of life depends on the maintenance of a concentration of salts in the blood proportional to those found in the sea, an experimental fact (Loeb) probably correlated with the marine origin of vertebrates.

Life depreciation is evident if we view the ill-effects of mineral deficiency. Just protein-carbohydrate-fat diet is disastrous. It means an acid laden system without any alkalies from mineral sources for neutralization. Intestinal putrefaction is immensely increased, a condition largely responsible for fifty per cent. of body impairment. Furthermore, interference with the body-regulating and stimulating powers will inevitably result in nervous and muscular disturbances—constipation, acidosis,

scurvy and what not. The familiar grouch is a living example of mineral deficiency in the diet. Keep the child blooming with a positive and ever-pleasant disposition by sufficient mineral salt provision.

In the table below the foods are arranged in the order of diminishing content of the essential mineral constituents per unit weight of fresh food compiled from Professor Sherman's tabulations in his "Chemistry of Food and Nutrition." Iron, phosphorus and calcium are listed because of the liability of inadequate provision in the child's daily ration.

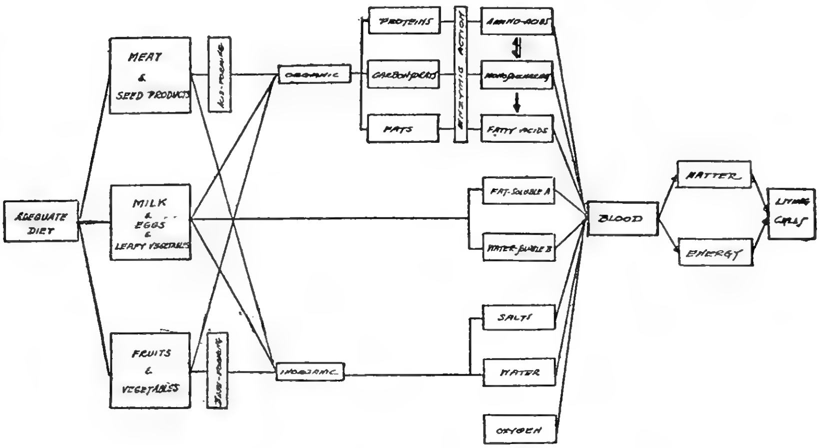

FIG. 3. THE METABOLIC COURSE OF FOODS.

Iron	*Phosphorus*	*Calcium*
Beans (lima, dried)	Beans (navy, dried)	Almonds
Beans (navy, dried)	Egg yolk	Beans (dried)
Peas (dried)	Peas (dried)	Egg yolk
Wheat (entire grain)	Peanuts	Milk
Beafsteak (lean)	Wheat (entire grain)	Peas (dried)
Spinach	Oatmeal	Oatmeal
Oatmeal	Almonds	Walnuts
Raisins	Walnuts	Peanuts
Eggs	Beef (lean)	Turnips
Prunes (dried)	Rice (polished)	Parsnips
Beans (string)	Parsnips	Carrots
Corn meal	Potatoes	Oranges
Potatoes	Turnips	Prunes (dried)
Barley flour	Beets	Wheat (entire grain)
Cabbage	Pineapples	Beets
Corn (sweet)	Bananas	Beans (dried)
Rice (polished)	Oranges	
Apples	Apples	
Milk		

Water as a Regulating Food

The internal body medium which makes vital processes possible is water. It is the most abundant cell and blood component. Common as it is water is endowed with the most wonderful properties, nature's special provision for its following regulatory functions: (1) maintains normal body temperature, (2) solvent and dispersion medium, (3) accelerates chemical reactions, (4) transfers heat between cells, (5) conveys food and oxygen to the tissues, (6) removes metabolic waste products, (7) coordinates metabolic processes.

The water content of the body is not a function of body weight, but of age. The infant needs four times as much water as the adult per body weight. This indicates that we are gradually "drying out" with seventy per cent. water content in youth diminishing to fifty-eight per cent. in adult age, but for the sake of growth beware "drying" the child, for tissue efficiency varies directly as the water content therein. Furthermore, the body carbohydrates and fats form stable dispersion systems with water—essential criteria for soundness of constitution. Any water deficiency for the child may result in (1) growth disturbances, (2) muscular slackness, (3) gastro-intestinal indigestion, (4) discordant metabolic coordination, (5) fluctuating fever, (6) increasing blood viscosity, (7) increased catabolism. Let the child have plenty of water during and between meals. A glass of water on rising and one on retiring will supplant many a purgative dose.

The Protective Foods

Biologic studies correlated with chemical have led McCollum and his co-workers to the recently extolled conclusions of profound importance in child nutrition that life perishes without foods containing fat-soluble A and water-soluble B. Faulty diets have been largely responsible for "deficiency diseases," *e. g.*, xerophthalmia, beri-beri, scurvy, pellagra and rickets. Adding these two unidentified substances brings about recovery. Insuring a non-appearance of any of these diseases, or rather making the child immune to them, lies in the ingestion of foods containing these two essential components. They stimulate growth and well-being probably by initiating and coordinating the protoplasmic formation reactions among the essential components prepared by the digestive processes. The more of them the child gets the better it feels.

The protective foods containing them are milk and the leafy vegetables. Here too their relative functioning is of marked gradation. As a matter of fact a nation's status may be interpreted from the standpoint of its utilizing milk or leafy vegetables or both as its protective foods. As McCollum puts it:

> Those peoples who have employed the leaf of the plant as their sole protéctive food are characterized by small stature, relative short span of life, high infant mortality, and by contented adherence to the employment of the simple mechanical inventions of their forefathers. The peoples who have made liberal use of milk as a food, have, in contrast, attained greater size, greater longevity, and have been much more successful in the rearing of their young. They have been more aggressive than the non-milk-using peoples, and have achieved much greater advancement in literature, science and art. They have developed in a higher degree educational and political systems which offer the greatest opportunity for the individual to develop his powers. Such development has a physiological basis and there seems every reason to believe that it is fundamentally related to nutrition.

Just as the sulphuric-acid output is the chemical barometer of a nation, so the amount of milk production is its health barometer. Milk has no duplicate, no substitute. It towers above all other foods. It is nature's best agent for child-building and a national wide provision must be made for its ready access to the growing child if our goal is human personality well grown and ready in body and mind.

The Child's Adequate Diet

Satisfactory nutrition for optimum child growth and development is attained by diets well-proportioned in the essential foodstuffs with plenty of water.

⅓	⅓	⅓
Milk.	Meat, Eggs, Seed Products.	Fruits, Vegetables and the Leafy Vegetables.

An additional dietary factor of vital importance, a daily American mispractice is the lack of balance of acid and base forming foods. If the nutrients are present in proportion to the body's requirement the bases will predominate. The foods below are listed in the order of their decreasing resultant acidity or basicity as demonstrated by Professor Sherman of Columbia University.

Acid-Forming	*Base-Forming*
Egg yolk	Beans (lima, dried)
Fish (haddock)	Beans (dried)
Meat (lean beef)	Raisins
Oatmeal	Celery
Eggs	Cantaloup
Wheat (entire)	Lettuce
Rice	Potatoes
Crackers	Oranges
Egg-white	Lemons
Cereals, meat and fish	Bananas
Acid Elements: Cl, S. P.	Cauliflower
	Cabbage
	Apples
	Milk (cow's)
	Fruit and vegetables
	Basic Elements: Na, K, Ca, Mg

The child's normal diet should consist of sufficient milk, fruits and vegetables to neutralize the acids formed from the other foods. The American custom of acid-forming dessert is largely the cause of her dental troubles at the child's early age. These sweet or starchy foods decompose in the interstices of the teeth with the production of acids which diminish the saliva alkalinity, flow and effectiveness. The acids further act upon the lime salts of the enamel, favor tartar deposition and pus formation in the alveoli, thus giving entrance to microorganisms which destroy the tooth structure. The French dessert principle is correct. It is a base-forming food—fruit. It is wrong for parental customs, conventions and idiosyncrasies to victimize the innocent child.

The quantitative feature as well as the qualitative is of important concern in dietary rationing. Waste of the rising generation is too evident for malnutrition through under nourishment not to be considered. It is well to abide by the child's total food requirement with greater per unit weight and also per unit surface than the adult's. In fulfillment of this requirement it is not necessary to use analytical scales or resort to extensive calculation of a man in full vigor at moderate work; the following fractional parts per age may be used to advantage.

Man	1.0
Woman	0.8
Boys (14–17)	0.8
Girls (14–17)	0.7
Children (10–13)	0.6
Children (6–9)	0.5
Children (2–5)	0.4
Under 2	0.3

Relative Total Food Requirement.

To recapitulate, the child's diet is different from the adult's in some of the following respects: (1) Natural and simple, (2) plenty of milk and leafy vegetables, (3) plenty of water, (4) no stimulants, (5) no highly seasoned foods, (6) hard foods during tooth development, (7) coarse, fibrous foods for smoothening teeth surfaces, (8) heartiest meal at noon, (9) no food between meals, (10) no sweets at the beginning or end of meal.

From the above considerations we realize that body needs are governed by natural laws formulated by science. The closer the adherence and the more intelligent the application of the available knowledge the higher the standard of public health and vitality. Educational reforms will bring the science of nutrition from the theoretical background to the practical front. For that indispensable service we need universal instruction in nutrition, dietetics, prophylaxis, child health; competent trained elementary school teachers and health visitors in nutrition and public health; infant welfare centers; social service staffs; more social-unit organization work under the auspices of the child-welfare leagues and child health associations; public cooperative kitchens; public demonstration centers; public-school child feeding; regular and periodic inspection of school children; more financial aid to mothers; more housekeepers' clubs; more public lectures on health, nutrition and sanitation. The public can not go to the schools; we must go to the public.

COOPERATION AND INDIVIDUALISM IN SCIENTIFIC INVESTIGATION

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THE dominant note in the papers and discussions of the biologists at the Baltimore meeting of the American Association for the Advancement of Science and the affiliated societies,[1] December 23–28, 1918, was the plea for greater cooperation among scientists. There were not wanting, however, those who maintained the need of individualism also, and its importance in scientific work. As a result one well-known botanist apparently expressed the feelings of some others when he said that after listening to the various papers he was left in a state of perplexity in regard to these matters. If such perplexity is at all general, it would seem desirable to try to discover its source and come to some better understanding as to the relation of cooperation and individualism in research.

In this case as in many others in which friends and colleagues fail to agree, the trouble appears to be largely due to a difference in interpretation of terms rather than in any real difference of opinion. Confusion of ideas and conclusions come frequently from lack of agreement as to the meaning of terms.

In discussing this subject, some seem to have taken for granted ideas which have not even been stated. As an academic proposition, most of us will agree that the chief aim of scientific investigation should be to advance knowledge and improve the condition of mankind. In attempting to attain the high ideals which are being proclaimed to-day by the leaders in all fields of human endeavor, we must not forget that if the majority of the

[1] The following are a few of the papers referred to: Livingston, B. E., "Some Responsibilities of Botanical Sciences," *Science*, N.S., 49, 199–207, February 28, 1919. Coulter, J. M., "The Botanical Opportunity," *Science*, N.S., 49, 363–367, April 18, 1919. Ransom, B. H., Osborn, H., "Methods of Securing Better Cooperation Between Government and Laboratory Zoologists in the Solution of Problems of General or National Importance," *Science*, N.S., 50, 27–30, July 11, 1919. Whetzel, H. H., "Cooperation among Plant Pathologists," *Cornell Countrym.*, 16, 13, 36, 38, 40, February, 1919; "Democratic Coordination of Scientific Efforts," *Science*, N.S., 50, 51–55, July 18, 1919. Lyman, G. R., "The Unification of American Botany," *Science*, N.S., 49, 339–345, April 11, 1919. Harper, R. A., "Stimulation of Botanical Research After the War" (unpublished).

individuals in any nation or group do not possess these ideals and take a deep personal interest in their attainment, no great progress will be made.

Cooperation

All are familiar with the ordinary dictionary definition of "cooperation." It is working together for one end or purpose. Cooperation has accomplished much in many fields of human activity. It has been asserted that cooperation won the great war and it undoubtedly was a very important factor. This accomplishment alone would naturally cause the word to appeal to us after having passed through the titanic conflict which has exterminated millions of human beings and is the direct result of the antithesis of cooperation, viz., competition of the basest and most malevolent type.

In cases where the destruction of individuals, families and nations is threatened, many gladly cooperate and work together for the preservation of life and property who would not be willing to forget their petty differences and prejudices and unite their efforts for less striking though equally important purposes in times of peace.

It must be recognized that it is only by organized cooperative effort that many of the great scientific problems now presenting themselves for solution can be successfully attacked. No single human mind can encompass all the knowledge necessary to solve many of the complex problems, which involve a profound knowledge of various branches of science.

Cooperation has been demonstrated to be of great importance in solving many of the problems presented in the present conflicts and activities of the human race. As scientists, we should determine if possible just how this plan can be applied most effectively to the solution of our particular problems. Cooperation in its broadest sense covers of course all interchanges of courtesies and assistance between investigators. If one is investigating an organism or group of organisms and a colleague supplies cultures or material of certain species, this is a simple form of cooperation. On the other hand, it may involve the intimate association of a group of specialists working together for years on some complex problem.

The advancement of science and the solution of its problems depend upon the availability of many materials, instruments and other facilities. Our laboratories, our apparatus, our libraries, our means of publication and illustration, either directly or indirectly are the result of cooperative agencies and activities. The phase of cooperation, however, with which we are most directly concerned at present is that which has been

undertaken in connection with scientific work carried on by individuals, offices, bureaus and institutions, in which investigators or institutions pool their interests, funds and men in attacking some broad problem. In such cases, if the investigators are responsible for carrying out the scientific work involved, they must come to some general understanding in regard to the division of labor, resources and other matters involved. In order to carry out such a project, the participants must be actuated by proper motives and not by selfish aims. Most of us will admit as a general proposition that selfishness is the chief source of our troubles in scientific work as well as in other human relations, but we are somewhat sensitive and hesitate to admit it so readily when the application becomes too personal. Few of us, I fear, however, will be prepared to plead entirely innocent.

It should go without saying that there can be no real or successful cooperation between persons who undertake the work in the spirit of horse traders, the chief aim being to see which can get the best of the bargain. Neither can successful cooperation be inaugurated and carried on by command or direction of those in authority. The cooperation must be voluntary and the problem attacked must be adapted to cooperative effort. Cooperation can not be applied to advantage in all cases and under all conditions. Its applicability and effectiveness must depend upon the particular problem and the individuals involved.

To attain the best results the participants should also be optimists, not pessimists. An excellent criterion has recently been proposed to classify individuals in this respect by determining their attitude toward oysters. The optimist is said to be always looking for pearls and the pessimist for ptomaine poison.

An obstacle to cooperation among organizations and institutions is the more or less artificial divisions of the field of investigation which have been made chiefly for administrative purpose, but which must sometimes be disregarded by mutual consent in order to attack and solve a problem most effectively and quickly. Unfortunately there are sometimes directors of scientific work who lack sufficient understanding of the problems involved to approve and encourage cooperation among the investigators who are naturally fitted for and willing to do such work.

Cooperation in scientific work is not comparable to joining hands in mere manual labor. In such cases we may simply lighten each others burdens or accomplish the task quicker. In cooperating on a scientific problem each worker should con-

tribute something which he is better fitted to perform than any other of the cooperators. The contribution of each differs chiefly in kind or quality instead of quantity.

It may be said that sufficient difficulties have already been mentioned to demonstrate the impracticability, if not the impossibility, of any general or effective cooperation in research. We refuse, however, to take such a pessimistic view of the situation and can not believe that the present generation of scientists is so hopeless. Our faith in the possibility and practicability of cooperation among scientists is not founded entirely upon academic grounds, but upon actual demonstration by experiment.

Many will be able to recall one or more examples of successful cooperation in attacking some scientific problem. To cite a specific case in phytopathology we may refer to the recent investigation of chestnut blight. Mutually agreeable cooperative arrangements were made between different offices in the Department of Agriculture and various experiment station workers to attack different phases of the problem. This cooperation was so broad that it included entomologists as well as physiologists, pathologists, taxonomists and chemists. By this arrangement all the varied aspects of the problem were studied, and much greater and more rapid progress was made in the solution of the whole problem than could have been made by any other plan. Unfortunately, lack of funds prevented carrying certain phases of the work to completion, but this was no fault of the plans or the investigators involved.

The problems in plant pathology being those with which we are most intimately acquainted we may be pardoned for citing an example of work which is typical of many pathological investigations in which cooperation is essential for success. Recently investigations of the cause and prevention of the decay and spoilage of fruit and vegetables in transportation and marketing have been undertaken. It was soon found that much more knowledge of the normal and pathological physiology of such plant products must be obtained. This required the service of specially trained, expert physiologists and biochemists. As many microorganisms were also involved in the decay, expert mycologists and pathologists were needed to solve the problems connected with their life history, relationships and physiological characteristics. Certain practical phases of the work also required the assistance of pomologists, refrigeration and market experts. It would appear self-evident that no one person could do the work necessary to carry such an investigation to a successful conclusion. It might be said that the problem could be separated into its various parts and assigned to physiologists,

biochemists, pathologists, mycologists and various other experts to work out by themselves. Experience has proved that the problem can not be economically or effectively solved in this manner. The various phases form such an intricate, complex problem that it is only by specially trained investigators working in closest cooperation and mutual understanding that the problem can be solved.

The best known general cooperative effort in plant pathology is that undertaken by the War Board of the American Phytopathological Society. In order to bring to bear as effectively and quickly as possible the available facts needed in preventing losses from plant diseases, especially of the staple food products and also to acquire as quickly as possible more necessary information, the board undertook to facilitate and encourage cooperative work among the men best fitted to attack the various problems involved. The essential features of the plan were voluntary offers of cooperation by the individuals and mutual agreement among the cooperators in the selection of a leader for each project. The results of the cooperative efforts inaugurated by the war board for the war emergency were so important and successful that the great majority of American pathologists have signified their desire to see the work continued as a permanent project. As a result, a new board called the advisory board of the society has been appointed and is specifically delegated to promote cooperative work among pathologists.

The familiar quotation from Shakespeare "There is a tide in the affairs of men which taken at the flood leads on to fortune" is especially applicable just now. If we interpret the signs correctly such a tide is now flowing and we should as scientists take all possible advantage of it. If according to the inscrutable plans by which the universe is guided, such a frightful slaughter as we have just witnessed was necessary in order to provide for the future advancement and welfare of humanity, it is not only an opportunity but a grave and imperative duty which presents itself at this time. The world as never before is looking to scientists for leadership, help and encouragement. The intellectual and spiritual battles which must be fought and won in the immediate future far surpass in importance the physical conflicts we have just passed through.

If the recently reorganized National Research Council lives up to the high aims set forth by the President in his executive order it will offer the greatest opportunity for organized cooperative effort in research that has ever occurred. It is to be hoped that it will be so supplied with the necessary funds and the support of all scientific investigators that it may fully demonstrate the advantages of cooperative effort in science.

Its measure of success must depend in great part upon the personel of the council. The importance of this is clearly and forcibly expressed by Dr. Hale, the former chairman of the council, in his invitation to the scientific societies to nominate representatives for membership in the council. He says:

> The future success of the National Research Council and the part to be taken by the United States in the International Research Council, of which it is the American member, will be chiefly determined by the representatives of the societies comprised in its membership. Recognized ability in research, wide understanding of its possibilities, keen interest in its promotion, and willingness to give time and thought to the work of the Research Council are the prime qualifications sought; whereas mere seniority in the profession, and scientific or technical activity without special interest in research, are evidently of themselves insufficient.

Every scientist and every scientific organization should take an active interest in the Research Council, giving it all the assistance possible, in order that it may carry out the great purposes for which it has been established. We should not only regard it as a great opportunity, but as a great obligation. The world is looking to us for cooperation and leadership in science as well as in political matters. Let us not disappoint it. We now have the necessary organization for cooperating with the various scientific organizations throughout the world. If this agency is properly utilized there should be a great acceleration in the advancement of science in the near future.

Individualism

It may appear to some that very little room is left in this scheme for individualism. The impression seems to prevail that there is a real conflict between the terms "cooperation" and "individualism." This we believe is due again to failure to properly define and understand the true significance and application of the terms. But a few years since, we were hearing much about the conflict between science and religion. To-day it is generally accepted that between true science and true religion there can be no conflict; both must have their basis in truth. The same may be said of cooperation and individualism. Between cooperation and individualism, in their proper application, there can be no conflict, for their aim is the discovery and application of truth. The chief problem is to determine the most effective manner in which each can be utilized in advancing science.

The fullest exercise of individual initiative, ability and expression in research, has in the past been most seriously interfered with by lack of encouragement and of funds and facilities, and by administrative restrictions.

It has been asserted that scientists, especially those endowed with extraordinary ability in research, should be free to follow unrestrained and unhampered wherever the spirit leads them. The best work in science as well as in art and literature must be primarily spontaneous and voluntary; but some guidance, some assistance and much encouragement may be given, the kind and amount depending upon the individuals involved and the problems under investigation.

Darwins and Edisons are rare. The future advancement of science must depend chiefly on the combined efforts of the mass of faithful seekers of truth whose names may never appear near the top of the scroll of honor of the world's greatest scientists.

Every effort should be made and every facility offered the individual investigator to utilize and develop in the most effective way all the ability for research which he may possess, but however brilliant the individual may be or however narrow or special his problem, cooperation in some form may be found advantageous. Individualism and originality should find full expression in the recognition of specific problems and their analysis and in the planning and carrying on of experiments and observations which give promise of leading to their solution or adding something of importance to the sum of human knowledge.

In general, special problems which do not require too great a diversity of knowledge of the various branches of science are best adapted to solution by individual effort, while broad and general problems can be more efficiently attacked by cooperation among individuals, each having free scope for the full exercise of his special training and ability in attacking some special phase of the general problem, the co-workers comparing results and coordinating their work by frequent conferences.

The applicability of cooperation and individualism in any particular case must be determined by the nature of the problem involved and the special ability and training of the investigators.

As we have tried to point out, there are plenty of problems and opportunities for the fullest exercise of the ability of the individual investigator as well as for cooperative efforts. The fundamental requirements for the success of either form of activity or combination of the two will depend largely upon the ideals and aims of the individual investigators involved. If their primary motives are love of research, the advancement of science and the improvement of mankind, there is not likely to arise any great difficulty in determining the best plan of work. If, however, baser motives dominate, the greatest success can not be attained.

IN REGARD TO SPECIES AND SPONGES

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IN the language of systematic zoology, species are particularly "difficult to distinguish" in certain genera, in many genera of sponges, for instance. Where this is so, it is in large part due to the fact that many specimens from various regions have been reported on. In such cases we begin to be face to face with the facts (of variation) as they are, not as they are assumed to be, when the species description rests on one or two specimens or on specimens from one locality.

A species in literature starts with the description of type specimens embodying a certain combination of characters, some of which are dimensional. As more or less similar specimens from different localities are studied, more and more such character combinations become known. These are of such a kind that, in sponges at least, if we consider any particular character, for instance the nature of the cortical canal spaces in the sponge *Donatia*, or the size and shape of the little spicules known as choanosomal asters in this genus, we shall often find, perhaps always find if we look long enough, forms that are intermediate between "species" in which the character in question has been regarded as a differential, that is, as a conspicuous mark of difference. That is, in respect to any one character there are species, and indeed often genera, which intergrade. Series of this kind indicate that the characters vary, or in the production of existing races *have* varied independently of one another.

As yet the most practical way of handling such complex data is to regard the race, usually geographical, which is represented by a described type, as the nucleus of a species that is gradually to be described. Round the race represented by the type specimens, and characterized by a certain character-combination, the so-called variations are gradually plotted. In this process racial or germinal marks are, it must be confessed, often confused through the limitations of the method with more purely somatic or environmental features. After a time, species-ideas emerge that are rich in content, and usable for all

kinds of biological work. Such species-ideas, however, owing to the way in which they have been built up, will undoubtedly sometimes overlap. When this becomes apparent, some rearrangement of the data (records) will be necessary, that shall be more in accord with the actual genetic relationships between the sponges and the causal nature of their differences. Such rearrangement, as we all know, has to be made from time to time. Species are combined, or distinct (hereditary) races within a species are distinguished, or marks that in the beginning were assumed to be racial are found to be age- or seasonal- or sex-marks, or the plain and simple results of a certain kind of local environment. All this is especially applicable to very inadequately known groups like the sponges, as it was equally applicable in former years to groups that are now better known. We must recognize, then, the necessity which is ever present with the classifier, of rearranging from time to time his categories.

In principle, systematists all agree with these ideas. Difference in actual practise comes in, however, when it is a question of assigning a place to a particular sponge or kind of sponge that has been described. Thus, to take an example, while very generally *Donatia ingalli* and *Donatia seychellensis*, the types of which differ noticeably in respect to the cortical anatomy, are retained as distinct species, some writers make them synonymous, viz., merge them. Of course, if in merging species the lines and magnitude of variation represented by particular races or strains (for so we may think of many literature species) are not lost sight of, no harm and often much good is done. But the merging can easily be arbitrary and artificial, as when only one or too few points of structure are considered, and the differences are slurred over, in which case distinctive characters that have been carefully recorded for this or that geographical region are lost sight of, and the process is simply the retrogressive one of "lumping" species together.

When one speaks of a species as embodying a certain character-combination, one may seem to be supporting the contention of Bateson, Lotsy and some others, that races are distinguished from one another as representing different combinations of germinal character-units, of units that have great stability; units which, moreover, are conceived of as comparatively limited in number and countable; units which are transported unchanged hither and thither through individual bodies, in the mazes of reproduction-cycles, combining, separating and

recombining again to produce by concerted action what formerly they produced (phenomenon of reversion). And it is undeniable that if we assume enough such units, we can use the hypothesis and possibly to advantage.

What is obvious, however, to the student of systematics and geographical distribution, although it must be frankly confessed that we are in the case of the sponges in great need of the intensive study of critical instances, is that racial features often vary up and down, apparently in response to the environment, in such a way as is possible only to easily alterable species-plasms.

One comes to symbolize the latter after the fashion of chemistry as complexes of atoms, molecules and radicals. Change in a complex may be pictured as due to the addition of more molecules or more radicals of a certain composition, or to a diminution in the number of such units. Or we may make the picture of fewer units, and think only of radicals which lose or gain atoms or simple molecules in response to environmental (external or internal) conditions, to "stimuli" as we say in physiological language. The radical thus varies up or down, and with it the features of the resulting organism. The rays of the small asters (chiasters) of *Donatia*, for instance, become obviously spinose at the tip, or are so minutely spinose that the fact is ascertainable only when an immersion objective is used, or are not spinose at all. In such a case, whether the germinal change be essentially one of a number of units, or quality of larger units, a graded series results, a series of idioplasms, of protoplasmic compounds, corresponding to the series of organisms which the study of differences exhibited by individual animals has led us to tabulate. The terms of such series actually in existence in nature at any one time may or may not be numerous. It would, however, seem, arguing from our knowledge that so many localities stamp with minute and yet distinguishable marks the individuals of a species living in such a region, that they often are very numerous. But whether numerous or few at any one time matters not. Artificial conditions bring into existence terms of the series never seen before, precisely as in the chemist's laboratory. And what does not exist to-day may come into existence in the future. Thus in respect to any character a series exists ideally, the terms of which are marked off from one another by minute, essentially dimensional, differences. Particular, easily distinguishable, terms of the series are recorded in systematics as among the

differential characteristics of species, when they occur with great constancy in a group of individuals; or as marking out a possible incipient species, when they occur only in some individuals, or when as in certain sponges they are represented only by some spicules of some individuals.

It is clear that the distinct categories of systematics or any classification, short of one that recognizes "individual-plasms," make an artificial set of frames for such boundlessly variable substances as are those that compose, let us say, the specks of protoplasm constituting the germ cells that will give rise to the organisms of the next generation.

It is no wonder, then, that although classifiers spend so much time in defining, viz., characterizing, particular species, no one can define the species-idea itself. Naturally this is so, because the species-idea is not precise, that is, it is not a definite complex of simple concepts, as was Linnæus's idea of species. The term stands only for a practical method of classifying things, which makes use, or tries to make use, of kinship as the chief guiding principle. Being of this practical character, it is in a measure apart from and implicitly contradictory of, our more precise physiological knowledge of nature, since its usage implies (of course, only on the face of things) that organisms do fall according to hereditary constitution into primary, separate groups of like significance. Nevertheless, as we all know, the employment of this practical rule, the species-idea, is a habit which helps toward the accomplishment of the great aims of biology, is indeed at present an indispensable tool in biological research.

The species-idea being of this kind, there is, of course, no definite number of species in the world, any more than there is a definite number of facts which, when found out, will constitute the perfect and closed book of a science. Reference is sometimes made to-day by biological writers to Linnæan species as if to groups of individuals that are qualitatively different from the groups which for convenience sake we put together under one name. Certainly the classifier of a group of organisms, as he extends his survey through the world, finds no counterpart in nature to an idea of a related set of individuals radically alike and radically different from all other sets.

What he finds is minute differences in the many times repeated, and superficially similar, structures of a single animal (the case of a sponge spicule, *e.g.*), differences between the individuals of a local race, and differences between groups of

individuals from different localities. Whatever distinction there is between individual (if hereditary) and specific differences, is one of degree not of kind. This is a commonplace in our book of principles, and has been since Darwin's time.[1] In the practise of the systematist the race is only a form "sufficiently constant and distinct from other forms to be capable of definition." And, as Darwin says,[2] if we call it a species, it is only because we regard its peculiarities as sufficiently important for the group of individuals exhibiting them to deserve a specific name.

It is convenient, as I have said, to use chemical symbolism. But what in the germ really underlies, what is the actual material basis of the individual differences which mark off races and species? Can we ever answer this question? Is it not simply one of those that turn upon the nature of matter, which physiological analysis of our sensations tells us need not, in strict logic, exist? At any rate, the kind of problem which we apparently can solve at the present stage of our mental development is not such as deals with the structural peculiarity in the idioplasm of the germ cell, the something which, if it exists, we may be allowed to call the final material cause of a character. It is rather how to produce the character, how to start and control the series of differentiations that lead up to its appearance. Growth and differentiation of the substance of germ cells and of tissues we certainly know something about, in the sense that our knowledge of these matters is perceptual knowledge and not symbolism, except in so far as all of our knowledge of matter is, to be sure, only a set of deductions, drawn from the interaction of ourselves and something which may or may not, we do not know, be what we now think of as matter. It is not misleading, it is not obscurantism, to point out that the "architecture of the germ plasm" about which we hear a good deal is for many (opinions differ—*vide infra*) a problem of a different kind from that which deals with the classification of germ plasms (idioplasms) on a basis of their perceptible properties, and with the laws that govern changes in these properties. These latter acquisitions of knowledge, although their form of expression, viz., the grouping of the facts, must needs be altered from time to time, rest on experience which repeats itself demonstrably when we wish, whereas the ultimate structure of an idioplasm will most probably forever lie within the field of symbolism. Such deductions follow after and fit them-

[1] *Cf.* "Origin of Species," sixth American edition, p. 412.

[2] "Origin," p. 425.

selves to experiential knowledge. It is the generalized results of the latter in the shape of comprehensive ideas or inductions, that tell us what we should expect in a concrete case and so lead to discovery. Beside these, theories as to the ultimate structure of this or that kind of matter are comparatively barren. And such theories should, I think, be more distinctly recognized for what they are, not over-rated and presented, as sometimes happens in inferior texts, in the guise almost of finalities, at any rate, as great, simple truths.

This feeling against the over-rating of theoretical explanation, with its concomitant effect on research in tending to develop the habit of substituting a partial conclusion drawn from one class of fact, for a thorough, comparative investigation of the phenomena, has been voiced in recent years by some of our leading thinkers.[3] So over-rated is theory, so habituated do we become to its use in school, university and public speechmaking, that, as we all know, it is deplorably common to find those who can not, try as they will, state their facts objectively. Such a schooling makes us all more or less inarticulate, except when allowed to speak in terms of our hypotheses, a condition which enormously increases the difficulty of ascertaining what has really been discovered in a field outside one's own. Goethe's verses, reading *experience* for *Leben* (although put in the mouth of Mephistopheles), are as true to-day as they were at the time of writing, when the imaginative portrayals by the biological logicians of the eighteenth century as to what goes on in development and inheritance, were so much nearer:

> Grau, theurer Freund, ist alle Theorie,
> Und grün des Lebens goldner Baum.

Finally, there is a question which all those who deal with the peculiarities and the classification of natural races and species do not answer in the same way. What place do the Mendelian genes occupy in our schema of the physiology of organic change, of the evolution of races? The gene is usually conceived as a self-propagating and stable particle of the germ plasm, which materially affects the sensible properties displayed by the organism into which a lump of such substance develops. It affects, at least in the speculations of T. H. Morgan and similar thinkers, not one but many such properties. The incorporation or loss of a gene is comparable to the incorporation or loss of a radical in an ordinary (non-living) organic compound.

[3] *Cf.* W. K. Brooks *passim* and A. Agassiz in his presidential address before the International Zoological Congress in 1907.

In bi-sexual development corresponding genes repel one another in such a way as to fall in different germ cells. With this latter idea, the work of the systematist gives no familiarity, and I therefore pass it by, remarking only that doubtless all the facts of the inheritance of traits, even where there is great variation in the offspring, can be brought into conformity with it, if we adopt multiple-factor hypotheses and assume the presence in a germ cell of many genes which cooperate toward the same end; a whole block of such genes, perhaps, as in simple Mendelian heredity, acting as a unit and repelling a corresponding block, while under other circumstances the block is disorganized and the separate genes act independently of one another, thus leading to a greater variety in the offspring, as in cases of "blended inheritance." Or we may explain miscellaneous variation in the offspring by using some other form of accessory hypothesis, such as that which postulates the presence of primary character-producing genes and of other secondary genes which determine through their cooperation the degree in which the character is developed.

Viewed in general as a component of the idioplasm, the gene fits into our knowledge of the peculiarities that differentiate races, and a place is provided for it in the chemical representation of a "species-plasm," already referred to as a usable concept, and which dates back at least as far as Haeckel's "Generelle Morphologie," where such plasms are referred to as "organic compounds." It is, as several have pointed out, the material representative of what we more usually call a hereditary trait. The graded series, for instance, formed by related idioplasms, in the Chalinidæ, for example, in which sponges the skeletal fibers range from such as consist of many rows of spicules with but little spongin, through term after term up to fibers consisting only of spongin with no spicules, these graded series, met everywhere in the sponges, are describable, as I have said, in the terms of chemical symbolism. They are equally describable in the language of the gene theory. In the latter case, we picture genes, reserving speculation as to their ultimate relation to the chemical structure of the germ plasm, some for the production of spicules, some for the production of spongin, each kind present in considerable number and all cooperating to produce the fiber. Perhaps symbolism of this kind will prove useful in lending precision to our thinking when we come more widely in zoological work to the experimental task of analyzing through the production of new forms, the forces that bring about change in organisms.

Are genes countable or not? Sometimes writers speak as if they were. In the world of imagery, they undoubtedly are in strict logic, just as atoms and molecules are countable on the basis of certain premises in non-living substances. But the hereditary properties to which they give rise, and which, after all, as Castle in particular has emphasized, are the only facts of which we have any (perceptual) knowledge, are, as every student of nature must admit, not countable, for as soon as a new property has been discovered, it proves to be but a door that opens to the discovery of still others.

The gene-idea is, as we all know, very commonly, although by no means universally, linked up with chromosomes. And it must be said that the linkage, if it really exists, in nature, carries the idea quite out of the world of symbolism into that of cellular physiology, the "architecture of the germ plasm" becoming then a real object for experimental study and not a mere subject for logical imagery. But it will not do to forget that the facts at least permit us, if they do not force us, as some maintain, to look on the visible material particles (chromatin masses), with which "characters" are associated (and the progress of genetic and cytological researches seems unquestionably to show that such exist) not as determinants, but as differentiations—as indeed the first conspicuous differentiations that are made by the idioplasm in the course of the chains of events which lead to the appearance of particular characters. Viewed in this light, chromosomes lose that air of finality with which the Weismannian philosophy has invested them, but retain a very solid interest. Genes, however, recede into the invisible.

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The records that make up biology would be chaos without systematics. Doubtless all will admit that much. Again, the interest in discovering new forms of life, new races and species, which is an essential part of systematics, is a basic factor in revealing what Arthur Thomson calls the "web of life," the complex of friendly and disastrous influences which species exerts on species in the matter of living. What is not so generally realized is that the classifying spirit and method, which works under comparatively simple conditions in systematics, and finds therefore in this field a chance to grow, is something that is needed in every branch of biology, if we do not wish to remain content with very provisional and partial conclusions

concerning the causes of phenomena, conclusions which sometimes succeed one another with a rapidity that dazzles and confuses all but the few engaged in their manufacture. This is only saying that science is nothing unless comparative. Systematics has, therefore, I believe, a great educational value.

But what direct significance have the results of systematics for the study of the laws of change in the organic world? Systematics reveals, at least in sponges, that characters are independently subject to variations such that in respect to any one of them, individuals and races occur which form close series between far distant extremes. Such series are found everywhere in the group. They are doubtless in a measure phylogenetic series, in which the terms bear to one another the relation of ancestral species and descendant. But the kaleidoscopic combinations of characters displayed in many genera and families indicate that this is not always the real relation. In these instances, it would seem rather that the terms of the series represent only different degrees in the response to the environmental stimuli, which related idioplasms have carried out independently of one another. Systematics thus gives us all the time hints, in some cases misleading perhaps, as to what *species-plasms can do,* and as to the conditions under which such and such a thing is done. It is a good guide to experiment, without which the latter is apt to run off into vagaries.

IGNIS FATUUS

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AMONG the meteoric appearances which have puzzled man ever since he began to inquire into the relations of phenomena and which are still unexplainable is the *ignis fatuus, jack-o'-lantern* or *will-o'-the wisp* as it has been variously called. Reference to this peculiar manifestation was much more frequent in the writings of one hundred years ago than it is at the present time and many people have come to think of it as a purely imaginary phenomenon, belonging in the same class with witches and fairies with which it is so frequently associated in literature. While there are, no doubt, many fanciful and highly colored accounts of this puzzling phenomenon, there are also many well-authenticated records of its observance by men thoroughly competent to pass upon its reality. There is, however, considerable divergence in the accounts of different observers, and it does not seem improbable that unfamiliar lights of different kinds have been classed under the same name.

Most observers speak of the *ignis fatuus* as a flame. Thus Benjamin Martin, in his "Philosophical Grammar," published in 1758, says:

> *Ignis Fatuus, i. e.*, the foolish Fire or Jack in a Lanthorn, when a fat unctuous vapour is kindled and wafted about by the motions of the Air, near the Surface of the Earth, like a Light in a Lanthorn,

and most definitions since that time seem to have followed this one as a pattern. However, Newton had long before distinguished between this light and a true flame. In the third book of his "Opticks" Newton propounds the following query:

> The *Ignis Fatuus* is a Vapour shining without heat, and is there not the same difference between this Vapour and a Flame, as between rotten Wood shining without heat and burning Coals of Fire?

In 1728, Mr. Derham, who had undertaken a special study of *ignis fatui*, laid before the Royal Society a letter from Dr. Giacomo Beccari, of Bologna, to whom he had written for information concerning these mysterious appearances. Beccari says, in part:

> What I am going to offer you, concerning these fiery appearances, is the result of several conversations I had upon this subject with several

experienced travellers, men of learning and reputation, whose sincerity I had no reason to mistrust. For my own farther satisfaction, ever since I received your commands, I have made it my business to speak with as many as I could light of, with such as travelled much in the mountains, and with others that observed them in plains, on purpose to see whether or no the difference of the place made any sensible difference in the appearance. I find upon the whole that they are pretty common in all the territory of *Bologna.* To begin with the plains, they are very frequently observed there; the country people call them *Cularsi,* probably from some fancied resemblance to those birds; and because they look upon them as birds, the belly and other parts of which are resplendent like our shining flies. They are most frequent in watery and morassy grounds; and there are some such places, where one may be almost sure of seeing them every night, if it be dark. In the fields near the bridge *Della Calcarata,* in a common, belonging to the parish of *S. Maria in dono,* north of *Bologna,* one of these fiery appearances is very often observed to move across the fields, coming from another bridge, called *Della fossa quadra.* There is another of them in the fields of *Bagnara,* almost east of *Bologna,* which scarce ever fails to appear in dark nights; particularly when it rains or snows; as also in cold and frosty weather: Both these, I mean that near the bridge of *Calcarata,* and that in the fields of *Bagnara,* are very large; and I am assured that sometimes their light is equal to that of one of our ordinary faggots, or bundles made of vine-branches; and that it is scarce ever less than that of the links which our country people make of hemp stalks, and which they light themselves withal, when they travel in the night. That at *Bagnara appeared,* not long since, to a Gentleman of my acquaintance, as he was travelling that way; it kept him company for a mile or better, constantly moving before him, and casting a stronger light on the road, than the link he had with him.

I believe there may be several more in other plains, as large as these two; tho' at present I have not been able to get certain information of any others. Lesser ones there appear a good many; some of them giving as much light, as a lighted torch; and some are no bigger than the flame of a common candle. Of these I have been assured a good many have been observed in the fields of *Barisella.* All of them have the same property, in resembling, both in colour and light, a flame strong enough to reflect a lustre upon neighboring objects all round. They are continually in motion; but this motion is various and uncertain. Sometimes they disappear of a sudden, and appear again in an instant in some other place. Commonly they keep hovering about six foot from the ground. As they differ in largeness, so do they in figure, spreading sometimes pretty wide, and then again contracting themselves. Sometimes breaking to all appearances into two, and a very little while after uniting again into one body; sometimes floating like waves, and letting drop some parts, like sparks out of a fire. I have been assured that there is no dark night all the year round, in which they do not appear. And in the very middle of winter, when the weather is very cold, and the ground covered with snow, they are observed more frequently than in the hottest summer. The Gentleman, who gave me an account of that at *Bagnara,* told me, that if I had a mind to see it myself, I might be sure of finding it, if I went thither in very cold weather; and in a sharp frost. Nor doth either rain nor snow in any wise prevent or hinder their appearance; On the contrary,

they are more frequently observed, and cast a stronger light in rainy and wet weather. This last circumstance, it is true, has been taken notice of by some writers, and among the rest, if I remember right, by the learned *Gassendus.* Nor does the wind much hurt them; tho' one should think, that if it were a burning substance, like common fire; it should either be dissipated in windy weather, or extinguished by rain. But since they do not receive any damage from wet weather; and since, on the other hand, it hath never been observed, that anything was thereby set on fire; tho' they must needs in their moving too and fro, meet with a good many combustible substances; it may thence be very reasonably inferred, that they have some resemblance to that sort of phosphorus, which doth, indeed, shine in the dark; but doth not burn anything, as common fire doth:

* * * * * * * * * * * *

As to the appearance of this phenomenon in mountainous parts, by what I have hitherto been able to learn, they differ in nothing else but in largeness; and all those I conversed with, that saw them in the mountains, agree that they never observed any larger than the flame of an ordinary candle. Nor do those that live in the mountains call them *cularsi,* which name is, perhaps, us'd only by the country people in the plains for those large ones above described. The difference of the air, and that of the soil, may, for ought I know, contribute a great deal towards the different sizes of these appearances; at least all I can offer material at present towards solving this particular circumstance, namely with regard to their largeness, is, that those grounds where we observe the largest fires, as at *Bagnara,* are what they here call *strong ground* (*terreni forti*) being a hard, chalky and claiey soil, which will harbour the water a long while, and is afterwards, in hot wether, very apt to break into large cracks and fissures: Whereas on the contrary, those soils in the mountains, where they observe the small fires, are what they call soft, or *sweet ground* (*terreni dolci*) being generally sandy, and of a more loose contexture, which do not keep the water so long as the others. Of that sort also is the soil in the above mentioned plains of *Barisella,* where about 7 or 8 years before, they observed a good many of the smallest *ignes fatui* in the fields within the compass of about 3 miles.

The above excerpts from Beccari's letter probably give the best second-hand information available at that time to one who was interested in science and who lived in a region noted for the frequency of the phenomena under consideration. They seem to show that there were at that time regions where these luminous appearances were of frequent occurrence and of large size. They seem to show also that the people who were familiar with them recognized a difference between them and a true flame.

Alexander von Humboldt also calls attention to this distinction. He says that in Cumana, Venezuela, flames are frequently seen at night which are visible at a great distance, but which do not set fire to the dry grass. In most cases, at least, they seem to give off neither heat nor odor.

The one recorded observation which the present writer has

been able to find in which the observer claims to have shown that this light was a real flame is quoted in *Poggendorff's Annalen* from the Italian *Annali di fisica,* etc., of 1841. The article is in the form of a notice from Dr. Quirico Barilli Filopanti, of Bologna. Filopanti begins by referring to a statement which was made to him by the painter, Onofro Zanotti that while passing along a street a fiery ball with the appearance of a flame rose from between the stones of the street near his feet, passed so near him that he could feel the heat on his face, and then very quickly disappeared. Filopanti became greatly interested in the narration and determined to try to see one of these lights for himself. He accordingly spent many evenings watching for the phenomenon, especially in the neighborhood of church yards, which he was informed were favorable places for seeing them. He says that his vigils were rewarded by the sight of three. Of these he says:

> The first was one of those which come out of the earth, rise to a certain height and then suddenly disappear. I can say little more of this than that it rose rapidly to a height of three or four meters and then disappeared with a faint report.
>
> The second was carried by the wind horizontally, and was followed by me for some distance, when it was carried over the water of the Idice and then disappeared.

The third gave Filopanti an opportunity to test whether it was a real flame. He states that after watching for several evenings in a place said to be favorable to the appearance of these lights, at a place where hemp was being rotted in a small brook near a church, he went into a peasant's house one evening to take shelter from the rain, which was falling. While watching from a window, he saw the wished-for light, and seizing a long rod with some tow on the end, which he had prepared for the occasion, he ran out and approached the light. He described it as a smoky flame, about a decimeter in diameter, which was moving slowly from south to north. As he approached it, it began to rise, but he was able to thrust his tow into it and see it ignite. Very soon afterward the light went out. He says that the burning tow gave a faint odor which was not like phosphorus, but which seemed to him to be of a sulphurous character with some odor of ammonia.

In Volume 41 of *Poggendorff's Annalen* is a notice taken from *Comptes Rendus* which says:

> On Sunday, Dec. 22, 1839, between five and nine o'clock in the evening, by mild and rainy weather, phosphorescent flames were seen to rise from slimy pools in the streets of Fontainebleau. These flames, when they rose from the water gave off a "crépitation" and wherever they were seen the

air was permeated with a strong odor of phosphorus. When the water from which the flames rose was stirred, it became phosphorescent.

This appearance, though classed under the head of *ignis fatuus,* was apparently quite a different phenomenon from those generally observed, as was the flame described by Filopanti.

A quite different description of an observation of these strange lights is given by the astronomer Bessel in a letter to the editor of *Poggendorff's Annalen* which was probably called out by the above notice. Bessel describes the observations which he made from a skiff on a small stream which flowed through a peat marsh as follows:

These appearances were observed by me on Dec. 2, 1807, early in the morning, on a very dark and calm night during which, from time to time, a gentle rain fell. They consisted of numerous little flames which appeared over ground which was covered in many places with standing water and which after they had glowed for a time disappeared. The color of these flames was somewhat bluish, similar to the flame of the impure hydrogen which is prepared by the action of dilute sulphuric acid on iron. Their luminosity must have been insignificant, since I could not observe that the ground under one of them was illuminated nor that the great numbers of them which frequently appeared at the same time produced a noticeable brightness. A closer estimate of their brightness I can not make, since the darkness of the night made my estimates of the distances of the flames very uncertain. Some of them, which seemed brighter than others, were estimated to be not more than fifteen or twenty steps distant, but this estimate is necessarily insecure.

As regards the number of flames which were visible at one time and as regards the period of their burning I can not speak with certainty, since both conditions were quite variable. I can only estimate as some hundreds the number visible at a time, and a quarter of a minute as the average period of their luminosity.

The flames frequently remained quiet in one position, and at other times they moved about horizontally. When motion occurred, numerous groups of the flames seemed to move together. I remember that one of the groups of flames suggested the moving of flocks of water birds.

Bessel describes the place where these observations were made as over a peat bog along a small brook. Much of the bog was covered with pits from which peat had been taken out, and pools of water stood in these depressions. It was over these pools that the lights appeared. He says that the boatman who was with him in the skiff, and who frequently carried peat through this marsh in the night, did not regard the appearance as at all unusual.

A similar observation to Bessel's was reported to the meteorologist Dove by *Schulrath* Looff, of Gotha. The observations in question were made by a student for whom Looff vouches. This student, Theodor List, was walking by night on a road

along the valley of the Fulda. The observation was described by List in part as follows:

The valley of the Fulda was covered by a heavy white fog, and a strong moldy smelling vapor filled the air. Suddenly, I saw a little flame scarcely two steps from me at the side of the road. I thought I must be deceived, but the moon was shining brightly and I was broad awake. To satisfy myself, I started toward the light, but when scarcely a foot distant it disappeared. But not a second had passed until I saw another, then a second, three, four, others. All the little flames remained quiet in one place and neither leaped nor danced. I observed that if the lights were not to disappear I must approach them very quietly, taking care not to set the air about them in motion. When I was very careful, I was often so fortunate as to bend over the little flames and observe their color and form at a distance of not more than a foot and a half. They were little flames of the size of a hen's egg, and they stood very quietly between the blades of grass. They were mostly of a greenish white light, and were fairly bright. I was able to seize some of them in my hand, but no heat was to be detected. If I waved a finger near them they disappeared at once. Many of them disappeared with a faint report, such as is made by the ignition of a bubble of phosphuretted hydrogen. Still, I must say that the air remained perfectly quiet.

A single flame seldom lasted longer than a minute and a half. The moon shone so brightly that I was able to read the dial of my watch. I could not have been deceived, for I observed the phenomenon very carefully and accurately. My eyes were completely clear, for I observed other objects about me and saw no lights between me and them.

A similar observation was reported by Galle as having been made by one of his students, Herr Vogel, of Leipzig. Vogel reports having seen *Irrlichter* twice, once along the marshy shores of a pond near Kamenz, and later just outside of Leipzig. The latter observations were made over a tract of marshy ground which received the drainage from some of the streets of the city, and through which a cut had recently been made by the Leipzig-Dresden Railway. The lights were seen in this railway cut. Vogel says:

After waiting for some time, I saw a faint light in the railway cut and observed a little flame about as bright as the vapor which is given off by a gently rubbed phosphorus match and very similar to this. This little flame disappeared very quickly, and after perhaps three seconds appeared again in the same place, and disappeared as before. I observed the phenomenon from a very close distance for several minutes without observing any odor. Likewise, I saw no smoke. The ditch was not filled with water, but its bottom was slimy. The little flames glowed about three inches above this slimy bottom, and were prehaps an inch high. The appearance was exactly similar to that which I had observed at Kamenz, only in that case the lights were much more numerous, so that it gave the appearance of the moon shining on rippling water.

Vogel states that the flames did not resemble those of spontaneously igniting phosphine, or of burning marsh gas.

A very different appearing *ignis fatuus* is described by Knorr, professor of physics at Kieff, as having been seen by him while a student at Berlin. Knorr describes two observations of these lights in his childhood, both of which correspond to the descriptions given by Bessel and List. The third seems to have been of quite a different character. This one, Knorr observed by the roadside at night where a bridge crossed a swampy stream. The light appeared in the grass over the marsh, and less than a foot beyond his reach when he lay on the ground. On account of the swampy nature of the bottom he feared to step into the marsh, but he lay near the light and observed it for a long time, passing his walking stick through it, and finally holding its ferule in the flame for fifteen minutes without it becoming appreciably warmed. He describes the light as of cylindrical form, perhaps five inches high and one and a half inches in diameter, standing quietly among the leaves of the marsh grass. He saw no smoke and observed no odor and the leaves of plants which were in the cylinder of light showed no signs of combustion. He describes the light as being bright enough to bring out plainly the surrounding foliage, though the night was very dark. The light did not seem to be easily disturbed by the movements of the air near it, and persisted until Knorr went on his way and left it.

Numerous other accounts of the appearance of these strange lights are probably familiar to the readers of this article, and many of them are, no doubt, of a fanciful character. Before the extensive draining of marshes over the earth, when these lights were more numerous than at the present time, they were regarded with superstitious fear by many of the people who most frequently saw them, and their accounts of them are, no doubt, frequently colored by this fear. One form of this superstition is shown in the name "corpse candle," which was applied to these lights in some localities.

Apparently different kinds of lights have been observed at different times. Certainly, the smoky flame described by Filopanti was quite different from the little clouds of luminous vapor described by Bessel, List, Vogel and Knorr. The present writer, when a child, was told by his father of lights which the latter had seen over a peaty pond in Ohio, and his description was similar to that given by Bessel, except that the observed lights were very few in number.

These little vaporous clouds seem to possess none of the characteristics of a flame of any kind. They are frequently spoken of as some kind of an electrical glow, and for the same

reason that many other phenomena which we can not explain are guessed to be electrical in their nature. However, the conditions under which these lights are seen are as far as possible from any under which an electrical glow is known to exist.

To the present writer, there seems but one probable explanation of these obscure phenomena, and that is that they are little swarms of luminous bacteria which are carried up from the bottom of the marsh by rising bubbles of gas. Many kinds of luminous bacteria are known and the marshes from which these lights arise are known to be the favored habitat of some of these kinds. Some, at least, of these bacteria do not become luminous until exposed to the oxygen of the air. This seems to be true of the bacteria which cause the luminosity of rotten wood, the "fox fire" of our boyhood.

In Volume 2 of *Nicholson's Journal* is described a rather extensive series of experiments by Nathaniel Hulme on luminous wood, fish, etc., in various gases. Hulme found that only air or gases from which oxygen could be derived would support the luminosity. It could be completely quenched in hydrogen, but after several hours immersion in this gas it would appear again if exposed to air or oxygen. Certain it is that bubbles of marsh gas and carbon dioxide gas are almost continuously rising from peaty marshes. The former, being lighter than air would carry its colony of bacteria rapidly upward until they were dissipated by diffusion. The latter, being heavier than air, would remain for sometime near the surface of the water, and would diffuse into the air much more slowly. Whatever would set up a circulation in the water would tend to dislodge these gas bubbles with their charges of bacteria from the bottom. Was not Newton probably right in his suggestion that there is "the same difference between this Vapour and Flame as between rotten wood shining without heat and burning Coals of Fire"?

LINKAGES

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A HISTORICAL study of linkages starts with the work of James Watt, although the pantagraph and lazy-tongs, both familiar cases of simple linkworks, were known at least as early as the seventeenth century. In his improvements upon the steam-engine the Scottish engineer found it necessary to guide the piston-rod in a straight line, and yet to communicate its motion to the circular movement of the working-beam. A diagram of his invention of the purpose is shown in Figure 1; the combination of three links provided an approximate rectilinear motion whose "sweet simplicity" was astonishing when contrasted to the double chains or racks and sectors which it replaced. In a letter to his son upon the subject he concludes, "Though I am not over anxious after fame, yet I am more proud of the parallel motion than of any other mechanical invention I have ever made."[1] Such praise from Watt is praise indeed; his interest in link motions was a lasting one, and he spent the later years of his long and splendid life in perfecting a machine for copying sculptures, a sort of pantagraph in space, which was to act with all the "delicate smoothness" of the parallel motion.

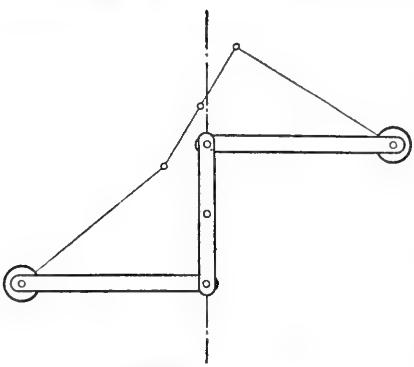


FIG. 1. WATT'S PARALLEL MOTION.

It was in the "latter end of 1783" that Watt devised the application to the steam-engine, but, in spite of the fact that it was almost universally used, very few adaptations or other combinations of links for the conversion of motion were tried for many years. Examples of Watt's parallelogram were given by engineering writers, such as the famous and influ-

[1] See D. H. Leavens, *Am. Math. Monthly*, Vol. 22, 1915, p. 331. He quotes from J. P. Muirhead, "Life of James Watt," New York, Appleton, 1859, p. 242. The reference to the second edition (London, 1859) is p. 288.

ential Frenchman, Prony,[2] but no comprehensive investigation was made until the middle of the nineteenth century, when the impulse came from the University of St. Petersburg.

In 1847 Pafnouty Lvovitch Tchebychef obtained a position at the University of St. Petersburg, and became able to indulge somewhat an interest he had pursued from a child,[3] the construction of mechanisms and models of his own invention. In the vacation of 1852 he took a trip through Western Europe to visit factories, to see different types of mechanisms and, most of all, to study Watt's parallel motion; towards the close of the summer he crossed the Channel to pay his respects to Cayley and Sylvester, and to Gregory the engineer. In London, Tchebychef hunted up some of Watt's original machines, preserved in the Royal Polytechnic Institute, and satisfied his inquiry by measuring the lengths of all accessible parts, and studying the details of the various arrangements.

On his return to Russia Tchebychef devoted a large part of his time and enthusiasm to the question of providing an analytical method for handling such motions as that of Watt's parallelogram. Recognizing the advantages of a geometrical insight into such motions, he nevertheless regretted the difficulty of a geometrical grasp of the subject, and for himself preferred methods of analysis. His own methods were remarkably clever, if somewhat prolix; and they enabled him to devise new motions whose deviations from a straight line were given in terms of arbitrary constants of the linkwork, and which were so inconsiderable as to be within the limits of mechanical accuracy.

But although these approximations may have been satisfactory from the point of view of mechanical motion, they were by no means a sufficient solution of the problem of drawing an exactly straight line. To accomplish this Tchebychef's analysis was unavailing. So far three links had been employed in every model, and the curve traced by points upon the traversing bar was beginning to be studied, a sextic of an analytically unattractive appearance. It was hardly likely that a five-bar linkwork, or a more complicated model, would produce a more simple result. Indeed, for more than three links Tchebychef's analysis grew so involved that a linear solution was extremely

[2] "Nouvelle Architecture Hydraulique," 1796, t. 2, p. 123. See Muirhead, second edition, p. 261. The terms "parallel motion" and "parallelogram," though not at all descriptive, are used throughout the early literature, and may therefore be retained here.

[3] A biographical sketch is given in Oeuvres de P. L. Tchebychef, St. Petersburg, t. 2 (1907), pp. i–vi, and his account of the trip, pp. vii–xix. (Cf. Leavens, *loc. cit.*)

improbable; and when he became certain that no three-bar motion could trace a straight line, he is said to have considered it impossible to produce rectilinear motion by any linkwork.[4]

But in this result the eminent Russian scientist decided "with less than his usual success in overcoming difficulties insuperable to the rest of the world," and it seems as though the spirit of science was merely waiting for this confession of inability to bring to men's attention the simplicity of the true solution. The first rectilinear motion by linkages was invented by Lieutenant Peaucellier, a young French officer of engineers detailed for the moment, and possibly with consequent leisure, to staff duty; a subsequent discovery was made by L. Lipkin, a freshman at the University of St. Petersburg, who was studying mechanics under Professor Tchebychef. Peaucellier's discovery was made about 1864, Lipkin's in 1870; and an interesting fact is that, although the two were independent, their methods and linkworks were precisely the same.

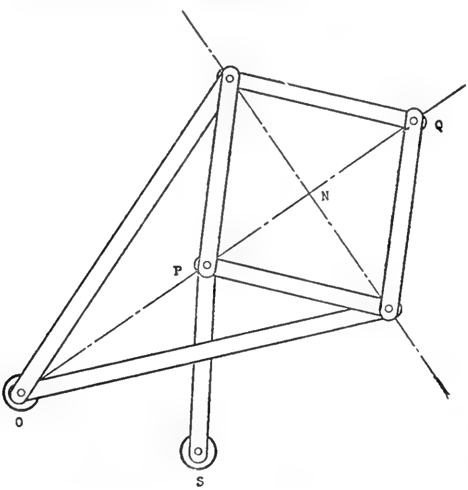


FIG. 2.

The linkwork of Peaucellier and Lipkin jumps from three to seven links. There are first of all two long links of equal length, both pivoted to the same fixed point; their other extremities are pivoted to opposite angles of a rhombus composed of four equal shorter links, as shown in Fig. 2. The portion of the linkage so far described is the essential part, and is called Peaucellier cell; by means of a seventh and extra link the cell is made to move so that the free end of the rhombus describes an accurately straight line.

The reasoning to prove this is very simple and depends upon a fundamental property of geometrical inversion. It is evident that whatever shape and position the linkage assumes, the points O, P, Q will always be on a line; and if N be the intersection of the diagonals of the rhombus,

[4] See J. J. Sylvester, "On Recent Discoveries in Mechanical Conversion of Motion," *Proc. Roy. Inst.*, Vol. VII., pp. 181 and 183, footnotes.

$$OA^2 = ON^2 + AN^2$$
$$AQ^2 = QN^2 + AN^2$$

so that

$$\begin{aligned} OA^2 - AQ^2 &= ON^2 - QN^2 \\ &= (ON - QN)(ON + QN) \\ &= OP \cdot OQ \end{aligned}$$

Hence if O is pivoted to a fixed base, since OA and AQ are the constant and arbitrary lengths of the links, the product

$$OP \cdot OQ = \text{constant}$$

so that whatever the shape of the cell, P and Q are inverse points with respect to a circle whose center is at O; and whatever curve P is made to trace, its inverse curve will be traced by Q.

So stated, the remainder of the problem is not difficult; for if we want Q to trace a line, an easy way will be to make P trace a circle passing through O, since the inverse of any circle through the center of inversion is a line. Hence the extra link, pivoted to P and to a fixed point S whose distances from O and P are equal. Then any motion of the linkwork will cause P to move on a circle through O, and Q will move along a line.

This pretty solution of the problem of rectilinear motion was published by Peaucellier in 1864; unfortunately not in a complete form, but merely as an announcement in the *Nouvelles Annales* for that year; and coming as it did from an unrecognized person in an unorthodox way it was "successfully concealed under a wrong entry." At any rate, the little announcement was quite overlooked by those interested, until six years later when the work was duplicated by the Russian student. Then Professor Tchebychef's admiration for the work of his pupil, although it confuted his own analysis, secured for Lipkin a handsome reward from the Russian Government. Tchebychef's enthusiasm communicated the results to his friends in France and England, and the stock in linkages rose. The hitherto unrecognized Peaucellier, now a colonel in command at Toul, was exhumed from his dugouts and awarded the famous "Prix Montyon" of the Institute of France; and it appears that the two young men who are here linked together for their independent yet similar abilities, were similarly sated by success, for neither Peaucellier nor Lipkin is again heard of in the history of science.

But if the younger men were resting quietly upon their laurels, their work was seized upon with complimentary rapidity by men of more maturity and standing; and at this juncture

the London school of mathematics became interested in the results which had hitherto been confined to engineers, and mostly obtained upon the continent. In 1869 Samuel Roberts suggested the connection between geometry and linkages in a paper read before the society "On the Mechanical Description" of certain curves.[5]

Mr. Roberts chose as his text the saying of Newton, "At æquatio non est; sed descriptio, quæ curvam Geometricam efficit," and considered that "in the present state of the theory of quartic and cubic curves, it is very desirable that we should be able to draw them continuosuly." He cited the classic examples of Nicomedes' Trammel for drawing the conchoid, Newton's method for the cissoid, and Pascal's for the limaçon. By generalizing these methods some interesting results were obtained; and among the more important results was the fact that Cayley became interested in the drawing of curves, and began a discussion of the three-bar curve, or the curve traced by any three-bar linkwork such as that of Watt.

The time was ripe for the introduction of Peaucellier's motion into England, and perhaps the dramatic way in which it was rediscovered by Lipkin had something to do with the interest it aroused. Consider the effect of a sincere statement by an eminent man that it was impossible to convert circular into rectilinear motion, a statement, by the way, which was confused by many with the squaring of the circle; and when this noted man had been for some time buried in a mass of computation to prove his point, a timid freshman raps upon the door, presenting to his eyes the thing itself, and not the proof of its impossibility. It was very likely this paradoxical entrance that pleased Sylvester. At any rate, Sylvester took up the invention with enthusiasm, enlisted Professor Henrici's services to procure him models, and at the annual general meeting of the London Mathematical Society in 1873 he gave a talk which was, by the secretary's account, "warmly applauded."[6] Following that, he made a well-known address[7] at the Royal Institute to a more general audience; and the enthusiasm with which that facile scientist spoke upon the subject to every one he met played a great part in its popularity, and the practical application which he foretold lent to it a specious importance.

The interest which Sylvester himself took in linkages is well

[5] S. Roberts, *Proc. Lond. Math. Soc.*, Vol. 2, 1869, p. 125.

[6] *Proc. Lond. Math. Soc.*, Vol. 5, p. 4.

[7] J. J. Sylvester, "On Recent Discoveries in Mechanical Conversion of Motion," *Proc. Roy. Inst.*, Vol. 7, p. 179; or "Collected Works," Vol. 3, p. 7.

attested by the address mentioned above; taken down by the secretary, it was probably given to the speaker for annotation; and when returned to the secretary for publication it had considerably more than five times as much in the footnotes as in the text, with a postscript superadded. In this postscript were included his "kinematical paradox" for representing a constant as a kinematical function of the independent variable, and several schemes for representing crystallographic and atomic groupings by means of linkages. "It would be difficult to quote any other discovery," he writes, "which opens out such vast and varied horizons as this of Peaucellier—in one direction, as has been shown, descending to the wants of the workshop, the simplification of the steam-engine, the revolutionizing of the millwright's trade, the amelioration of garden-pumps, and other domestic convenience (the sun of science glorifies all it shines upon), and in the other soaring to the sublimest heights of the most advanced doctrines of modern analysis, lending aid to, and throwing light from a totally unsuspected quarter on the researches of such men as Abel, Rieman, Clebsch, Grassman, and Cayley. Its head towers above the clouds, while its feet plunge into the bowels of the earth."[8]

Although Sylvester's words read rather like an advertisement than sober science, his enthusiasm was adopted by many round him and the models were admired by many more. He showed a model of Peaucellier's cell to Sir William Thomson, and according to Sylvester the canny Scot "nursed it as if it had been his own child, and when a motion was made to relieve him of it, replied, 'No! I have not had nearly enough of it—it is the most beautiful thing I have ever seen in my life.'"[9] Considering the extraordinary conversions worked with the model, Sylvester considered that "it would not be unsuitable to write in letters of gold on the board attached to it which gives support to the two frail centers, the famous motto of Constantine —'In hoc signo vinces.'"

With Sylvester pushing the subject from one side and Cayley from the other, the interest in linkages could not fail to be keen, and many other men were drawn to the subject; A. B. Kempe and Harry Hart in England, Lemoine and Brocard on the continent, Woolsey Johnson in America, and an even more notable trio, Darboux, Clifford and G. H. Darwin. Within ten years close to one hundred and fifty papers had been published

[8] Sylvester, *loc. cit.*, p. 195. His spelling, Rieman and Grassman, is preserved.

[9] Sylvester, *loc. cit.*, p. 183.

in recognized journals;[10] and if a curve is plotted as in Fig. 3 to show how many papers were published every year, as an indication of the interest, such a curve would show a remarkable rise during 1874, and its culmination reached in 1875 with thirty-six articles published in that year. The rapid rise of

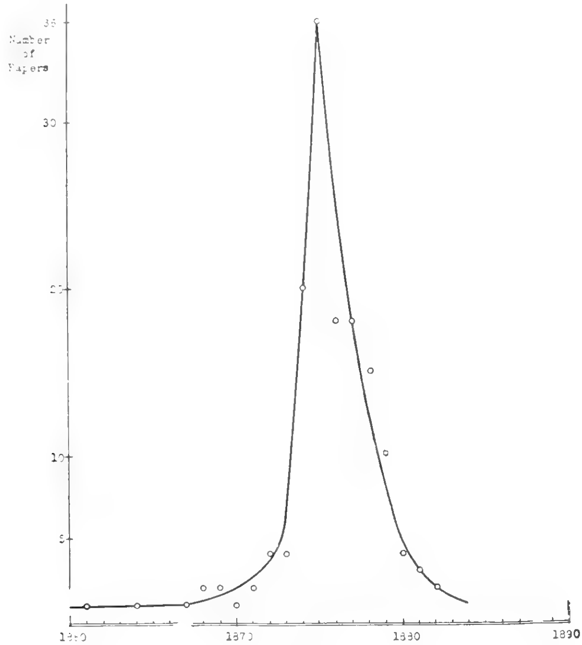


FIG. 3.

the curve is no more remarkable than its sudden fall; and the shape in general is typical of an explosive epidemic, due to powerful causes, and rapidly running its course to a conclusion.

Peaucellier's motion was introduced by Sylvester into England in 1873, and many up to date mechanics seized upon the principle. Some circular steps outside St. Paul's Cathedral were so worn as to require repair, and the surveyor used a cell, adjusted to circular instead of rectilinear motion, to cut the templets; and though the radius of the steps was about forty feet, the cell operated "to the great comfort and delectation of his clerk" with a link some six feet long.[11] It was, by the way, this same surveyor whose pump was "ameliorated" by Peaucellier's principle. And a little later came the classic example which all students of linkages quote, the application of the motion to the air engines which ventilate the House of Parliament.

[10] V. Liguine, *Bull. Sci. Math.*, 2d series, Vol. 7, 1883, p. 145, gives a bibliography of 151 papers up to 1882.

[11] Sylvester, *Proc. Roy. Inst.*, *loc. cit.*, p. 182.

In August of 1874 Harry Hart of Woolwich Academy disproved Tchebychef's last entrenchment[12] by showing that Peaucellier's cell of six links could be replaced by a new linkage of only four bars. Hart's linkage was obtained by crossing the links of an ordinary jointed parallelogram, as in Fig. 4, form-

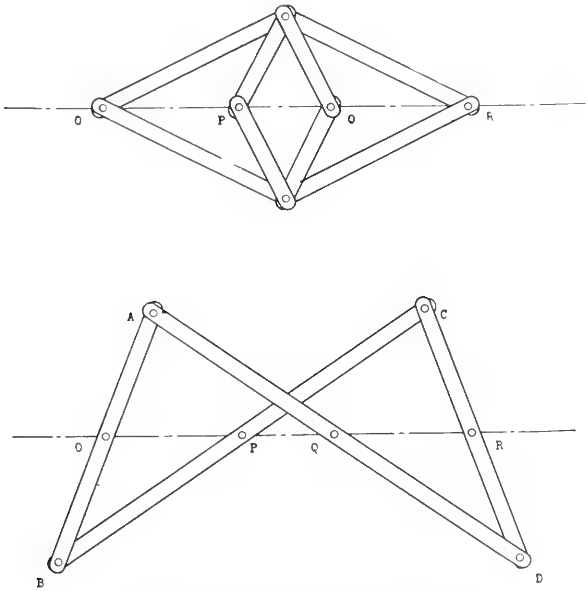


FIG. 4. HART'S CONTRA-PARALLELOGRAM.

ing what is called a contra-parallelogram. Then the four midpoints[13] have exactly the properties of the points of a Peaucellier cell to which two long links have been added for symmetry; and it follows that a five-bar rectilinear motion may be produced from Hart's contra-parallelogram by the addition of an extra link.[14]

So far linkages had been studied from an experimental standpoint, as arrangements of a certain number of rods and pivots; but about this time Samuel Roberts suggested that instead of considering the motion of jointed rods it would be better to consider the motion of the planes associated with those rods, for the order of the path-curves would not thereby be increased. Sylvester then substituted the more general idea

[12] Tchebychef stated the impossibility of five-bar rectilinear motion, even after Peaucellier's discovery was known. See Sylvester, *loc. cit.*, p. 181.

[13] Or any points whose ratio $AO:OB$ is constant.

[14] A different and pretty five-bar linkwork for drawing a straight line was given by M. Raoul Bricard in 1895 [*Comptes Rendus*, 120, p. 69], but as not related to the general story of the epidemic it is not included here.

of the relative, as distinguished from the absolute, motion of plane upon plane; a conception which is fruitful in indicating that link-motion may be reduced to the rolling of centrodes.[15]

In studying the ordinary three-bar motion it had occurred

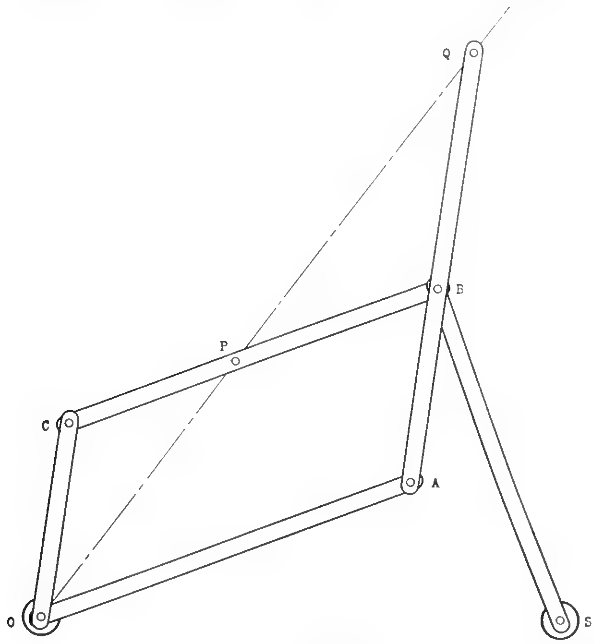


FIG. 5. PANTAGRAPH.

to Kempe[16] to consider what happened when the traversing bar and one of the radial bars had changed places, and the conclusion reached without difficulty was that the order in which the bars are chosen does not affect the shape of the path-curve. If, in Fig. 5, OC, CB, BS be the original three bars, and P a point on the traversing bar tracing a certain curve; then if the two bars OA, equal to CB, and AB, equal to OC, are added, and Q is on AB such that

$$QO : PO = AO : CO,$$

Q will trace a curve similar in shape and position to that traced by P, but enlarged in the fixed ratio. And if the bars OC and CB are taken away there remains a three-bar linkwork which is the same as the old except that the radial link and the traversing link are interchanged. This was remarked by Sylvester as a most acute and admirable theorem; but is also, as Cayley

[15] See Sylvester, "History of the Plagiograph," *Nature*, Vol. 12, 1875, p. 214, footnote.

[16] A. B. Kempe, "How to Draw a Straight Line," London, Macmillan, 1877, p. 20; Sylvester, *loc. cit.*, p. 215.

observed when Sylvester consulted him, a self-evident deduction from the principle of the ordinary pantagraph.

The result obtained by Kempe, when communicated to Sylvester, was immediately seen by the latter to be extensible to the case of three-piece motion, where the bars are replaced by their planes; and Sylvester's skew pantagraph or "plagiograph" is obtained by making P and Q similarly situated in the

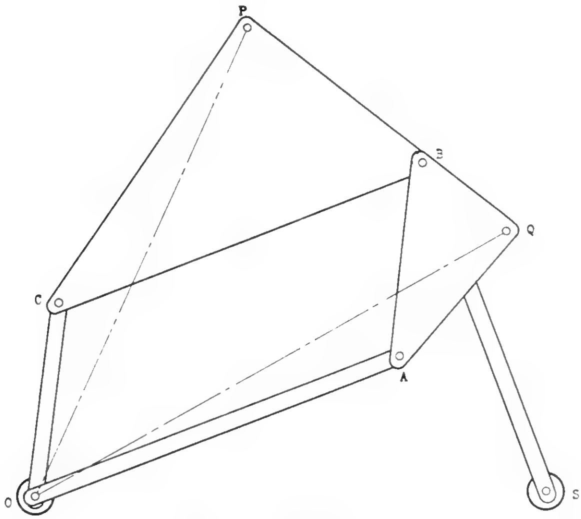


FIG. 6. PLAGIOGRAPH.

planes of CB and AB, as by making the triangles CPB and AQB similar, in Fig. 6. Then P and Q trace curves which are similar, but turned through a fixed angle.

It is a natural conclusion that the principle of the plagiograph might be applicable to Hart's contra-parallelogram, and both Kempe and Sylvester, the one "by the free play of his vivacious geometrical imagination," the other "by the sure and fatal march of algebraical analysis," found that if a chain of similar triangles be attached to the four links, the free vertices will form a parallelogram whose angles are invariable and whose area is constant. For instance, to use the same lettering in Fig. 7 as in Fig. 4, if O, P, Q, R are the vertices of isosceles right triangles fixed to the bars AB, BC, AD, CD, then $OPQR$ is always a rectangle of constant area. The linkage is, by Sylvester's name, a "quadruplane."

The quadruplane affords much light upon three-bar motion, which results when any one plane is held fixed. If, for example, AB is fixed, then I will be the instantaneous center, and

$$AI + BI = BI + CI = BC, \text{ a constant.}$$

so that the point I describes upon the fixed plane an ellipse of

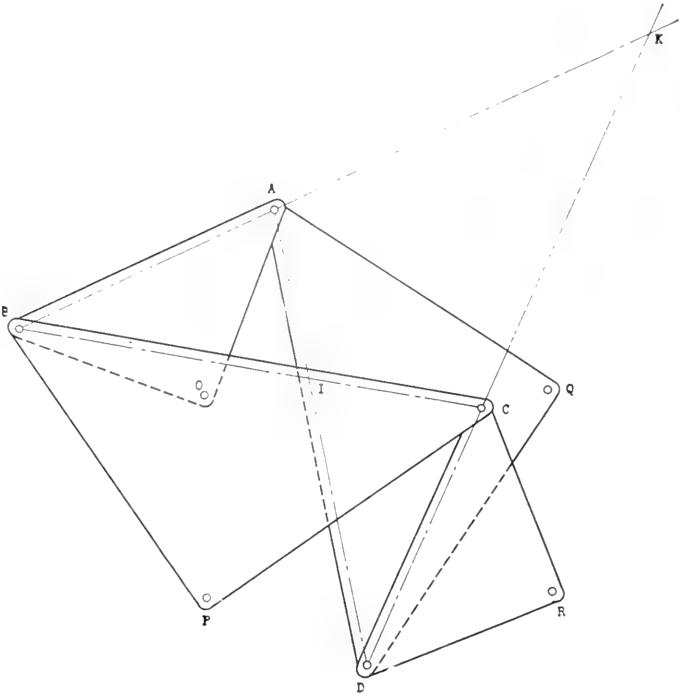


FIG. 7. QUADRUPLANE.

which A, B are the foci and BC the length of the major axis. In a similar manner

$$CI + DI = DA$$

and the locus of I on the moving or traversing plane CD is an equal and similar ellipse. Hence the relative motion of the two opposite planes AB, CD, is that produced by the rolling of two equal and similar ellipses.

The two planes BC, AD have their instantaneous center at K; the trace of K upon the plane BC is given by

$$BC - CN = BN - AN = BA,$$

an hyperbola, and its trace upon the plane AD is an equal and similar hyperbola. It follows that the free motion of the quadruplane, or the relative motion of four planes so linked, reduces to the double rolling of two ellipses and two hyperbolas.

This conception of three-bar curves being produced by the rolling of two equal conics shows that the particular quartics produced are related to the inverses of conics, and simplifies the discussion considerably; and in broad terms this represents the state of knowledge of three-bar motion through the middle of

1875, when Sylvester had published an article in *Nature*. In November of that year Samuel Roberts made an important observation in the theory of three-bar motion proper, or the motion of three links about two fixed pivots. Noticing that the pivoted points turn up as singular foci in the discussion of the sextic path-curves, and that there are three foci to the sextic, he suggested that the two pivots might be placed at any two of the three foci, and by means of links of suitable lengths the same locus would be obtained. In other words, any path described by a point moving with three-bar motion may also be described in two other ways by three-bar motion.[17]

Whatever the merits of Mr. Roberts per se—and this observation was singularly acute—he seems to have had the important ability to interest Professor Cayley; and once again Cayley was led to an investigation of three-bar curves by a consideration of Roberts's results. In March of 1876 he put the above theorem into the following elegant form.[18] Take any triangle *ABC* and through any point *O* within it draw lines *KF*, *EH*, *GD* parallel to the sides. Let the triangles *HKO*, *GOF*, *ODE* be supposed rigid and jointed together at *O*, and let the other lines in the figure represent bars forming three jointed parallelograms, as shown in Fig. 8. Then however the system is moved about in its plane the triangle *ABC* will always be of the same shape; and further, that starting from any given position of the three triangles, the linkage may be so moved as not to alter the triangle *ABC* in magnitude; so that when the three points *A*, *B*, *C* are fixed in any other than their maximum position, the point *O* will still remain movable. In so moving, *O* will describe a path which is due at the same time to three different three-bar motions.

These pretty results were proved by Cayley with a somewhat forbidding nomenclature, and Clifford, who usually sat in the back of the room and said little at the meetings of the society, gives a very much simpler discussion in his "Kinematic."[19] But the two papers which Cayley read at this time contain much information on the three-bar curve; and, though they by no means say the last word upon the subject, no further word was said for quite a time. For reference once more to Fig. 3 will show that in 1876 the interest in linkages had passed its climacteric, and that the number of papers published and

[17] S. Roberts, *Proc. Lond. Math. Soc.*, Vol. 7, p. 17.

[18] Cayley, *Proc. Lond. Math. Soc.*, Vol. 7, 1876, p. 136; cf. Clifford, "Kinematic," p. 149.

[19] Clifford, *loc. cit.* Curiously enough, the same simplification was published as original by Hart [*Camb. Mess. Math.*, Vol. 12, 1882, p. 32], while Clifford's "Kinematic," surely a widely read book, came out in 1878.

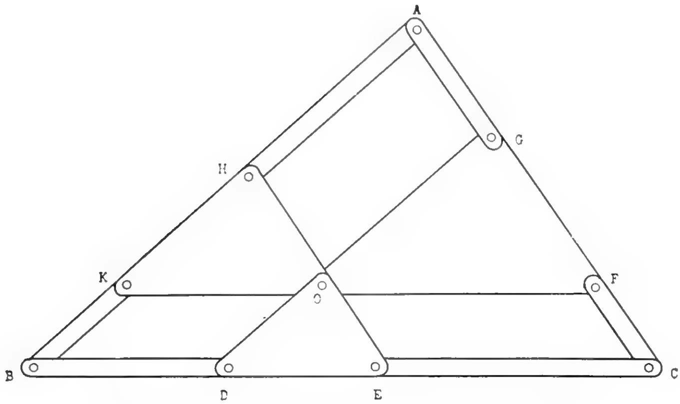


FIG. 8. TRIPLE GENERATION OF THREE-BAR MOTION.

new results obtained was rapidly diminishing. One stopping point upon the downward course occurred when Kempe proved the rather remarkable theorem that any algebraic curve whatever can be described by a linkwork, and his analysis is as beautiful as his result is elegant.[20] But after that the enthusiasm fell as fast as it had risen, and the epidemic, as far as history is concerned, was over.

Sir William Osler quotes Sidney Smith as saying, it is not the man who first says a thing, but it is he who says it so long, so loudly, and so clearly that he compels men to hear him—it is to him that the credit belongs; and so far as this singular epidemic of linkages is concerned, the credit for its existence belongs to Sylvester. It was through his efforts that other great minds turned to the subject; and indeed, the subject is made more interesting than many other offshoots of science only by the notable character of its contributors. And it may be more than a coincidence that the epidemic failed just at the time when Sylvester became involved in building up a new department in another land. The students at the Johns Hopkins University were interested in other lines, and though there are several papers on linkages in the *American Journal of Mathematics*, there are none of great importance. In England, Cayley and Kempe were diverted to map-coloring and the study of groups; of the younger men, Darwin found another line more suited to his taste, and the incomparable Clifford died before we had a chance to learn what he might have done. With the loss of the contributions of these leaders the first chapter of a study of linkages may close.

[20] Kempe, *Proc. Lond. Math. Soc.*, Vol. 7, 1876, p. 213.

THE PROGRESS OF SCIENCE

LORD RAYLEIGH

THE death of John William Strutt, third Baron Rayleigh, closes a career of remarkable scientific distinction and may mark the ending of an era in science and in civilization of which he was one of the finest representatives. The loss of the environment supplying men such as Darwin and Rayleigh is part of the price that must be paid for industrial democracy, developing through the nineteenth century and now rising to sudden supremacy through the catastrophe of war.

A significant part of the Victorian England was the life and work of its two great universities. Strutt entered Trinity College, Cambridge, nearly sixty years ago, and received his degree as senior wrangler in 1865, twenty years after William Thomson, later Baron Kelvin, had been second wrangler. The remarkable selective power of the Cambridge mathematical tripos examination is further shown by the fact that the senior wrangler in Thomson's year, Perkinson, was a mathematician of distinction, while the second wrangler, following Strutt, was Alfred Marshall, also later professor at Cambridge and England's most distinguished economist.

Rayleigh married Evelyn Balfour, who was a niece of the Marquis of Salisbury, author, prime minister and president of the British Association; she was a sister of Mr. Balfour, also author, prime minister and president of the British Association. The two other brothers of Lady Balfour were also distinguished, Francis Balfour, professor of animal morphology at Cambridge, being a brilliant investigator. Her sister, Mrs. Henry Sidgwick, wife of the distinguished Cambridge professor of ethics, was an able scientific writer and investigator, becoming later principal of Newnham College. The oldest son of Lord and Lady Rayleigh, who now inherits the title, is professor of physics in the London Imperial College of Technology and the author of important contributions to the science.

Clerk Maxwell, the great mathematical physicist, was the first Cavendish professor of physics at Cambridge. On his death in 1879 he was succeeded by Rayleigh who held the chair for five years only. His student Sir J. J. Thomson, succeeded him at the age of twenty-seven. Thomson retired this year from the chair to which his student, Professor Rutherford, has now been elected. It would perhaps be impossible to name a chair in any subject or in any university held in succession by four men of such distinguished performance. The family and academic relations of Rayleigh indeed witness the efflorescence of the aristocratic tradition.

Rayleigh established his laboratory at Terling Place on his eight thousand acres of land and did his work, usually with simple apparatus. His book on the "Theory of Sound" is a classic. His "Collected Papers," published in five volumes in 1910, comprise 349 titles, and, as he continued to publish without cease, his recent papers will fill a further volume. Each of these papers is a contribution to knowledge; none of them is commonplace. To the general public Rayleigh is best known for the discovery of argon which opened a new chapter in physics. This he accomplished simply by the use of the balance, finding a new

Lord Rayleigh.

element truly as common as air, for it forms one two-hundredths of the atmosphere.

Rayleigh was for eighteen years professor of natural philosophy at the Royal Institution; he was for eleven years secretary and for five years president of the Royal Society; he was president of the British Association when it visited Montreal in 1884; he was chancellor of the University of Cambridge until his death; he received a Nobel Prize and all the honors that go to men of science. During the war and when over eighty he rendered great service to the progress of aviation as chairman of the National Committee on Aeronautics. With unusual truthfulness it can be said "we shall not look upon his like again," for the scientific and social conditions of his life will not recur.

REFORM OF THE ENGLISH UNIVERSITIES

FROM the days of Newton to Kelvin, Stokes, Maxwell, Rayleigh, Thomson, Rutherford and Larmor, the University of Cambridge has been the home of mathematical physics. Newton entered Trinity College in 1666, and was elected a fellow in 1667. During the subsequent two hundred years until Rayleigh was elected to a fellowship in 1866, the college, which was especially frequented by the sons of the nobility and of the upper classes, produced a long line of men of distinction, including many mathematicians. Sir J. J. Thomson, second wrangler in 1880, was elected to a fellowship in that year and is now master of the college.

Oxford and Cambridge, which with about one tenth of the number of the students claimed by Columbia, have been responsible for the education of more than one half the leaders of England, and England has had more great men than any other nation. It is a noteworthy circumstance that these universities, medieval not only in religion but also in their whole outlook on life, should have this record. It seems necessary to assume that the able men of a great race were drawn to Oxford and Cambridge rather than that an

NEVILLE COURT, TRINITY COLLEGE

obsolescent system of education was responsible for their performance.

Oxford and Cambridge have already been reformed by act of parliament, and it is now proposed to repeat the performance with the labor party as the power behind the British throne, rather than men such as Larmor, the mathematical physicist, who represents Cambridge in the conservative interest in parliament. The announcement of the plans of the government were made by Mr. Fisher, a former university professor, now minister for education, to a deputation from the educational committee of the Parliamentary Labor Party, which urged the desirability of an inquiry into every aspect of the two universities. Mr. Fisher informed the deputation that the authorities of both universities had agreed to the principle of the inquiry. He gave an undertaking that the government would carefully consider the question of the representation of the labor movement and of women on the commissions.

The labor members, in presenting their demands, suggested that the scope of the inquiry should be so wide as to include the finance of the two universities, their endowments, constitution and government, and their relation to other parts of the national system of education, including the education of women. The deputation reminded Mr. Fisher that since the last public inquiry into the two universities the educational system had been revolutionized. Further, the number of students who could profit by study at Oxford and Cambridge had largely increased. The deputation declared that the labor movement desired that every man and woman capable of pursuing an education at the two universities to good account should be able to obtain it. They suggested that the end of the war was a specially suitable time for the inquiry which they sought, and declared that the financial arrangements of Oxford and Cambridge offered *prima facie* some ground for believing that considerable economies would be made possible by a better system of administration—for example, by the greater centralization of the revenues now received by the colleges.

A demand was made for a thorough overhauling of the administration of the colleges with a view to diminishing the cost of living in college, which they estimated to be rarely less, and generally considerably more, than £100 for six or seven months' residence and education. That, it was contended, excluded the sons of men of small means, unless they were assisted by scholarships or exhibitions. The deputation definitely asserted that no systematic effort had been made by all college authorities to reduce the cost of residence and education to the lowest point compatible with efficiency. It was added that working people did not accuse college authorities of any deliberate policy of exclusiveness.

The deputation also asked for the thorough overhauling of the present system of awarding scholarships and exhibitions. It was stated that working people thought it highly improper that a money prize for a term of years should be awarded to a man who did not require it when so many men were debarred by financial difficulties from receiving a university education. Their view was that scholarships should be used to assist men who without assistance would be unable to meet the cost of an Oxford or Cambridge education.

Among other recommendations the deputation proposed that the constitution and government of the two universities should be reformed in such a way as to create a central body in each which would have effective control over the whole of the revenues and would compel the col-

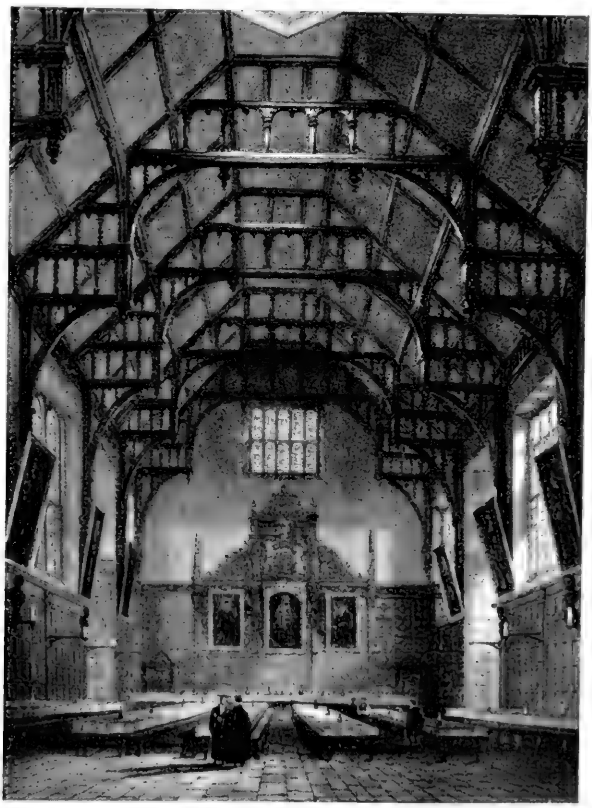
leges to submit to its requirements—for example, in reducing the cost of living and in appointing lecturers and fellows. They also pressed for the inclusion on the governing body of each university of the representatives of the outside public, nominated by the Board of Education or otherwise, and for the abolition of the power of convocations to veto university legislation. Other points to which the labor deputation attached importance were the granting of degrees to women and the development of extra-mural university education.

Finally, the deputation assured Mr. Fisher that labor was strongly in favor of a far larger public expenditure upon universities as upon all other kinds of education. But they contended that, until Oxford and Cambridge were reformed, they could not properly be assisted by the grant of public money.

SCIENTIFIC ITEMS

WE record with regret the death of Gustaf Retzius, the eminent Swedish anatomist and anthropologist. Professor Retzius's father and grandfather were also distinguished Swedish professors of natural history and anatomy.

DR. THEODORE W. RICHARDS, professor of chemistry at Harvard University, has been elected president of the American Academy of Arts and Sciences. Professor Alexander



THE HALL OF TRINITY COLLEGE.

Smith, head of the department of chemistry at Columbia University, has been granted the degree of doctor of laws by the University of Edinburgh.

THE will of the late Andrew Carnegie was filed on August 28. Mr. Carnegie's gifts to charity during his life are said to have exceeded \$350,000,000. The value of his estate is estimated at between \$25,000,000 and \$30,000,000. The will contains a series of legacies, the most substantial of which are to educational institutions. The Carnegie Corporation of New York. He is the residuary legatee.—It is announced that Yale University will receive approximately \$18,000,000, about \$3,000,000 in excess of the expectation of the university corporation, from the estate of John W. Sterling.—Edward F. Searles, of San Francisco, has given stock valued at \$1,500,000 to the University of California for its unrestricted use.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1919

THE PSYCHOLOGY OF DAYLIGHT SAVING

By Professor GEORGE T. W. PATRICK

THE STATE UNIVERSITY OF IOWA

NOTWITHSTANDING the President's veto, a bill repealing the daylight saving law in the United States was passed by an overwhelming majority in the Senate and House. One senator had on his desk a petition for the repeal of the law signed by more than one hundred and twenty thousand names, all from one state. In a typical mid-west town of twelve thousand, a straw vote revealed more than ten to one against the plan. Daylight saving in America thus passes for the moment into history and by many unthinking people will no doubt be remembered as a crazy freak of theorists or an unholy attempt to meddle with the clock.

Nevertheless, daylight saving is sure to be revived and there are already strong movements throughout the country to introduce it again next summer in separate communities. Furthermore, the statement may be made and easily maintained that the daylight-saving plan is thoroughly sound and desirable both from the economic and scientific standpoint, wholly conducive to public welfare and practically free from serious objections.

The formidable array of arguments marshaled against the plan on the floor of Congress were riddled with fallacies, which a little patience and candor might have exposed. Any careful and serious consideration of the subject was prevented by a wave of reaction and the clamor of the farmers of the middle west who were inconvenienced by the law. It was simply another instance of a clamorous minority and an indifferent public.

Now that the law has been repealed and we have leisure to study the subject more carefully, it will be instructive to examine some of the grounds for daylight saving and some

of the arguments against it. There are also certain curious psychological factors in the case, which it will be interesting to observe.

On the face of it, daylight saving seems to be an unmixed gain. The law provided that the clock should be advanced one hour every spring and set back one hour in the fall. Unfortunately in this country the change was made to take place too early in the spring and too late in the fall, a mistake that should be remedied in any future attempts. Now, since few people get up at daylight in the summer, the daylight saving plan gives us an extra hour of sunlight in place of an hour of artificial light in our waking day. Since sunlight is cheaper than gas or electric light, being absolutely free for the taking, and since it is also brighter and healthier, and since, furthermore, the plan involves no change in the routine of our daily life, merely substituting one hour of sunlight for one hour of darkness, it would seem at first view that there could be no possible objection to it, except on the part of the gas and electric companies.

If we note also the fact that the plan has been adopted by practically all the European countries, resulting in an enormous saving in expense in artificial lighting and adding apparently to the health, happiness and comfort of the people, the mystery deepens as to the cause of the objection to it in this country. The subject offers a unique chapter in popular psychology and reveals certain new features not hitherto brought into the discussion. Although sunlight is cheaper, healthier and brighter than artificial light and more convenient even than pressing an electric button, it appears that people *prefer* the artificial light and the reasons for this preference have to be taken into account. If these reasons are valid, then, in spite of all the conspicuous arguments for the plan from the economic, hygienic and social point of view, we might still have to revise our opinion as to the value of it.

But first let us orient ourselves on the whole subject. It has been determined that adult men and women need about eight hours of sleep daily. This leaves sixteen hours of the twenty-four for our waking life. In the platform of labor parties, for instance, we read of eight hours for work, eight hours for sleep, and eight hours for recreation. Now it happens that in the summertime in the latitude of New York and our great middle west, the daylight day is sixteen hours in length. It is light at about four in the morning (that is, by the old

time) and darkness falls at about eight in the evening. After eight o'clock it is necessary to use artificial light. Thus the natural daylight day in the summer months exactly fits the human working day and there is no doubt that during the age-long history of man on the earth, reaching back hundreds of thousands of years, he has been accustomed to rise at daylight and go to sleep at dark, as do the birds and other lower animals. Only the predatory birds and animals, who have found it to their advantage to prey upon the quiescent nocturnal life, reverse this order.

Gradually, however, with the invention of artificial light, and especially since the invention of the electric light, there has come about a displacement between the daylight day and the human day, so that now we rise two or three, or even four or five hours, after daylight and remain up two, three, or even five or six hours, after dark, using artificial light. This displacement has taken place in human history very recently, just yesterday, relatively speaking. Even as late as the time of the Greeks and Romans, there was relatively little displacement. In one of Plato's dialogues the young man Hippocrates thumps loudly on Socrates' door before daybreak, eager to hasten to the place where Protagoras, the celebrated sophist, was instructing Athenian youth.

The reasons for this displacement of the human working day are interesting. We shall inquire presently into this curious bit of psychology. But the displacement itself is going on faster than ever at the present time, owing in large part to the discovery of the convenient, brilliant and fascinating electric light. Every year it seems to be a little harder to go to bed or to get up at the old accustomed time. Automobiles, unlike the horse, travel as well at night as by day and keep increasingly late hours. College and high-school students study later at night or engage in social activities. To go to bed early is not just the thing. It is a little out of date. To meet the requirements of our complicated modern life, more and more industries continue through the night, for instance, railroads and steamship lines, hotels, police service, news collecting and newspaper printing, etc. Quite apart, however, from these necessary night occupations there is an increasing tendency to shift the day farther and farther forward. Without doubt the number of people who sleep till noon is constantly increasing. If the matter is left to adjust itself, one naturally wonders how far we shall go in the substitution of night for day. Will day and night finally be wholly transposed?

Apart from psychological considerations, this displacement of the day seems to be the purest kind of folly. The morning hours with the noisy singing of the birds and the streaming light of the sun are not well adapted to sleeping. At nightfall, which in the summer takes place at about eight o'clock by the old time, nature is still and the conditions for sleep are perfect.

This loss of the morning sunlight was so evidently a net loss to the nation, that the daylight-saving plan was devised to correct it. It does not attempt to correct the whole discrepancy between the natural day and the human working day, but only one hour of it. And it attempts to do this not by making any change whatever in our daily program, but simply by setting the whole program one hour earlier by the sun, leaving it precisely as before by the clock. It is as if a good God had said:

> My people have shifted their day so that they lose two or three hours of the precious morning sunlight and have to use artificial light in the evening. How shall I correct this? In order not to disturb their habits or their customs or their clocks, I will quietly order the sun in the summertime to rise one hour later and set one hour later at night. This will bring their day and my day more nearly together and many of them will hardly know that any change has been made. They will simply enjoy the sunlight an hour longer every evening.

Of course, the same effect could be accomplished by advancing in the middle of some dark night every clock in the land. This was the way that Congress attempted to attain the desired end. So far as the daylight-saving law has failed of its full benefits, it has been because many of us did not understand that we were to make no change in our daily schedule. We should have gone on precisely as before in every detail. If we had been accustomed to rise at six o'clock, breakfast at seven, go to school at nine, lunch at twelve, dine at six and retire at ten, we should have gone on doing all these things at precisely the same time by the clock. Then no change or disturbance whatever would have taken place in our lives, only we should have enjoyed an hour's additional sunlight in the evening.

True, the great majority of us did this and we have found the added sunlight the greatest benefit. We have enjoyed our morning's sleep better because it was dark and quiet. Then the day has followed exactly as before, except only that when we have gone to work at the usual hour the sun was not so high nor so hot and, it being summertime, this has been greatly appreciated, for the last hour of our work in the afternoon had often been very hot and uncomfortable, and now we have been free during this last hour. This has given us after work

at night or after school a delightfully long evening for play or sport or picnics, or, if we prefer, for work at home. The home garden has become more popular and this added hour of sunlight after working hours has given many of us an opportunity to work in our gardens or with our flowers. To be sure, under the old plan we could get up in the morning and work in the garden, but the gardens in the morning were wet with the dew and work was unpleasant. The result has been a very large increase in the number and size of our gardens, with a corresponding increase of wealth and health.

Now that the war is over, if the daylight-saving plan should be continued, decided benefit in respect to morals may also be expected, for darkness is a cover for every evil thing. We know how our cities and towns in the interest of morals flood the streets, alleys and parks with electric light. Sunlight accomplished this end so much the better.

Still greater will be the benefit to our national health. Sunlight is the enemy of almost every form of disease. The substitution of an hour of daylight for an hour of artificial light means for many of us another hour of outdoor life with outdoor sports or outdoor work. An hour of lamp light means an hour of indoor life. Since some of our most insidious modern diseases are the results of our increasingly sedentary and indoor life, the benefit of the daylight-saving plan to our national health must be obvious.

Incidentally too there will be a decided benefit to the eyes. Our modern life involves so great a strain upon the eyes in reading and in all manner of fine work, and so much of this reading and writing is done at night by the aid of artificial light, that the substitution of an hour of sunlight for gas or electric light will be of supreme value to us. In fact we are coming to realize that something must be done to relieve the strain upon the eyes. Statistics from our recent military draft showed that nearly thirty-five per cent. of our young men were physically unfit for military service, and of the various defects causing this unfitness defects of the eyes stood at the head of the list, more than one fifth of all the rejections being due to this cause.

While no doubt the greatest advantage of the daylight-saving plan is in the matter of health in the substitution of sunlight for artificial light one hour each day in the summer, nevertheless it is the saving in expense which appeals to us most forcibly. Artificial illumination in homes, parks, streets,

hotels, railroad stations and in all shops, offices, stores, etc., that are open in the evening in summertime must begin under the old plan about eight o'clock in midsummer and earlier in the spring and fall, while under the new plan it begins an hour later. The city of Vienna is said to have reduced its gas consumption in one summer by the daylight-saving plan by 158 million cubic feet, resulting in a saving of $142,000. One of the large electric-lighting establishments in Paris reported that when the clock was turned back in October its nightly peak load of 35,000 kilowatts of current jumped in a few days to 53,000 kilowatts. It is estimated that England saves $12,-500,000 in coal annually by the new method and the saving for the United States is estimated at $25,000,000 annually.

The coal supply of the world is not going to last forever. Many think that the shortage will soon begin to be felt in this country. Coal for keeping us warm in winter and in lighting our homes in winter is indispensable. To lie in bed in the morning when the sun is shining and then use our precious supply of coal for illumination at night would seem to be an inexcusable extravagance. Conservation of coal will soon be absolutely necessary. It may well begin by daylight saving. The saving in coal, however, is only a part of the total financial gain of the new daylight plan.

If under such circumstances it seems difficult to explain the opposition to the plan, the difficulty is increased when we recall the general favor with which the plan has been received in European countries and indeed with large classes in America. On June 14 of the present year *The Literary Digest* published the results of a wide inquiry among labor unions and workingmen's organizations as to the opinion of laboring men about the daylight-saving law. With very few exceptions wholly favorable responses were received from mine workers, electric workers, laundry, brewery, flour, cereal, flint glass, garment, soft drink, and boot and shoe workers' unions and from organizations representing machinists, hod carriers, blacksmiths, barbers, pressmen, and from hotel and restaurant workers. Furthermore, the new plan appears to be very favorably received by physicians, lawyers, university men, public-school teachers and business men. It gives them longer summer evenings for gardening, motoring, golf, etc.

The immediate cause of the attempt of Congress to repeal the law was the loud and vigorous protest of the farmers against it. If we consider the unusual and unparalleled prosperity of

the farmers during the time in which daylight saving has been in force, and furthermore the rather unconvincing character of the arguments which they brought against it, and still further the very feeble fight which advocates of the plan offered in its defence, it becomes evident that there were other factors involved in the situation. One of these factors no doubt was the extreme conservatism of the American people and their dislike of any legislative action which seemed to interfere with the established routine of their daily lives. The change to standard time, for instance, which was effected by act of Congress some years ago and which has resulted in great benefit and convenience, met with serious opposition in many quarters and it is said that the old time is still adhered to in some localities. Again, all attempts to discard our antiquated and inconvenient system of weights and measures and to substitute the scientific metric system have met with opposition. For a body of legislators at Washington to interfere with the affairs of our daily life and tell us what time to get up and what time to go to bed was carrying things too far. As a war measure we could submit to this or any indignity, but not in time of peace. When the daylight-saving scheme was first brought forward in England and America it was opposed even by men of science, and if the farmers have offered unsound arguments against it, so did the scientists. It was argued, for instance, by the English journal, *Nature,* that England should not adopt the plan for the reason that it had been adopted by Germany and that Germany had probably adopted it because England had not! This writer closed his editorial with the remark that daylight saving would be a leap in the dark! This was every bit as bad as the farmer who wrote to his local paper that the crazy daylight law should be repealed because working in the corn-field in the early morning brushed the dew from the corn. A slight computation would have shown this writer that the chances of any given hill of corn having the dew brushed from it *once* during the summer, owing to the earlier hour of the farmer's day, would be only one in ten. Many letters were written by farmers and farmers' wives to local papers protesting against the unholy interference with God's time.

But let us consider the real arguments against the plan of daylight saving as they were presented by the farmers through their representatives in Congress. One objection was that the hottest time of the day was between twelve and one o'clock (according to the old time) and under the new plan the farmer

and his horses must be back in the field during this hour. This argument has all the appearance of being manufactured in some newspaper office, for any observing farmer knows, as any thermometric chart will show, that the hottest part of a summer's day is not at that time, but between two and four in the afternoon, usually between two and three. In midsummer in the Mississippi Valley the maximum temperature occurs at about three o'clock, while even at six the temperature has fallen often only three degrees Fahrenheit. The great difference between the temperature of the first morning hour of the working day and the last evening hour, reveals the advantage of the new plan to all workers during the hot weather, since it substitutes the cool morning hour for the hot evening hour.

Second, it was complained by mothers, not only in the country but in the city, that under daylight saving the children could not get ready for school in time, since it began an hour earlier. The reply to this is, of course, that school does not begin an hour earlier but at precisely the same time, namely, at nine o'clock. If the children were accustomed to get up at five, six, seven or eight o'clock, they could continue to do so under the new plan and would have the same time for preparation as before. In any case they would not have to get up before light, for it is light at five o'clock by the new time in midsummer and at half past five on May 1. It is probable that the children slept later under the new plan and they slept later because they sat up later. In other words, they did not fully accept the daylight-saving plan but made a change in their hour of retiring, when it came into effect. Indeed if school began at seven, there should be no difficulty in getting there on time. It's a matter of habit. The church hour has been gradually put later and later until now it is at eleven o'clock, and yet many people are late for church.

Third, it was complained that the dairymen had to get up earlier in the morning, perhaps before daylight, in order to get the milk ready for the morning trains. Incidentally one can not help noting here a psychological factor, namely, our willingness to use artificial light in the evening but our dislike to using it in the morning. No doubt the advancing of the clock has made it necessary for some dairymen to get up before daylight and has caused them considerable inconvenience. But for these dairymen to ask that the rest of the hundred million people of this country should sleep another hour every morning in order that they, the milkmen, should not have to get up before day-

light would be unique, to say the least. If, for instance, we imagine a great nation accustomed to get up at daybreak and go to bed at dark and living in large cities and demanding fresh milk for their breakfasts, some one would have to get up before light to supply the demand. This inconvenience could no doubt be avoided if all the people except the dairymen should sleep several hours later in the morning, but no sane man would propose to remedy the difficulty in this way.

Seen in this light, the other difficulties experienced by the farmers fall into their proper perspective. In advocating the repeal of the law, the farmers have laid special stress upon two difficulties. First, owing to the dew, the early morning hour is not favorable for farm work. And second, if to avoid this the farmer begins and ends his day's work at the former time, his hired men make trouble, since they wish to stop work when the town and city people do. Furthermore, if the farmer works an hour longer than the city people, he is late for any entertainment or meeting which he may wish to attend in the city in the evening. As these difficulties were presented to the country, they were offered as separate and cumulative objections. They are, of course, alternatives. If the farmer begins his work an hour earlier than formerly and experiences trouble from the dew, he does not experience the other troubles, and *vice versa.*

Perhaps none of these difficulties is so serious as was imagined. The complaints about the dew came principally from the farmers of the Mississippi Valley and pertain only to haying and harvest time. The dew does not interfere with other farming operations, such as plowing, disking, seeding and planting and cultivating corn. During harvest time, as the dew is sometimes on the grass and grain until nine or ten o'clock, it is often in any case necessary for the farmer to begin and end his work at later hours. The need of synchronizing farm and city hours of labor during three or four weeks of the year is not so great as to ask a whole nation during the whole summer to begin its day's work an hour later in the morning and live by artificial light an hour later at night.

It was also loudly proclaimed by the opponents of the daylight-saving law that if the city people want to get up earlier in the morning, they can do so, but let them not meddle with the clock. But if the city people got up earlier, they would begin their working day earlier and the farmers' two difficulties would appear as before. And it should be remembered that it is a question of social welfare in which everybody is interested

and that the habits of the people will not be changed, although theoretically they could be, without some concerted legislative action. It is probable that the farmers themselves, when the matter has been accurately presented to them, accustomed as they are to rise and retire early, will welcome a change which shall encourage other people to do the same.

It turns out, therefore, that the objections to the daylight-saving law are rather petty and not of serious moment. Perhaps the strongest objection is one which apparently was not urged by the opponents of the law, namely, that a great many people in America have to sleep in upper rooms which are very hot in the evening and that they therefore sit up until it is cool and so under the new plan do not get enough sleep. There are no doubt ways in which this difficulty may be met and it is not of such seriousness as to weigh against the exceeding great benefits of the new plan.

After all, the psychological factors of the situation are the ones which present the greatest obstacles to daylight saving. There is a certain fascination about artificial light and a certain human predilection for night life that must be reckoned with. Whatever the reason for this preference may be, it is so strong that if by legislative action we were to set forward the clock one hour both summer and winter, in the long run it is probable that nothing would be gained. We should soon be getting up an hour later by the clock, should go to school at ten, to church at twelve, and our whole daily schedule would be correspondingly advanced. It is only by adopting the plan for the summer months that any really permanent advantage may be gained.

But what is the cause of this shifting forward of the human day so that it no longer corresponds with the solar day? Why do we tend to get up later and go to bed later as the years go by? There are several reasons and the psychologists are able with considerable success to fathom them. The first is a very simple and evident reason. As life becomes complicated and interesting, it is difficult to get through with the duties of the day in the usual time and so we sit up later at night, and then, in order to obtain the necessary sleep, we have to get up later the next morning—and the habit grows.

Another minor cause is found in the fact that at night, when most of the world sleeps, some will find it to their advantage to be awake. Just as certain predatory birds and animals roam or prowl at night to take advantage of the sleepers, so certain human occupations, lawful and unlawful, flourish under cover

of the darkness. Certain kinds of crime flourish at night and night is proverbially the time for love making in all its phases. Many students, writers, inventors, etc., work at night simply because it is quiet and greater mental concentration is possible. Some night workers report a peculiar feeling of power and sovereignty at night, as though one possessed the world. Obviously, however, these advantages of night work will disappear in proportion as the night hours are used by all. Already the morning hours are becoming the really quiet time for work. Those who find the night hours better for concentrative or creative work have formed an expensive mental habit. If the habit were reversed, the morning hours after refreshing sleep would be found the most productive as well as the most economical.

But probably the real reasons for our ever increasing night life are of a profound psychological nature. There are two distinct principles involved here. First, artificial light exercises upon us a peculiar fascination not possessed by sunlight. This is due to certain mental associations coming down from the primitive life of man. Fire is the original source of artificial light and fire and light are associated in the mind. The camp-fire or the fire on the hearth suggest feasting and joy after the labor of the day and in winter suggest warmth and comfort. After the strenuous labors of the day in forest and field comes the pleasant relaxation of the evening, and whether this takes the form of feasting or dancing or music or the telling of tales, the camp-fire is the center of this joyous social life. This deep-seated association fixed by centuries of ancestral habit explains that peculiar feeling of pleasure which we have when the lights are lighted at night. When theatrical performances are held by day, no matter how well lighted the theater may be, we all prefer to darken the windows and use the electric lights, while the lure of the great city is partly due to the glitter of the brilliantly lighted streets and places of amusement.

The other reason for the peculiar charm of night life is due to still more recondite mental associations. To live by night and sleep by day is a sign of class distinction. The man who works at common manual labor must rise with the sun and go to work. Not so the leisure classes. They can rise when they choose and sit up as late as they wish. Night life, therefore, gives what Professor Thorstein Veblen would call "honorific status." It is only another case of "conspicuous waste." To go to bed early is not just the thing from the social point of view. To sit up late is a sign of a certain "invidious distinction." To

sit up very late or to lie in bed till noon is a sign of affluence. We often boast of late hours but we are a little ashamed of going to bed early. In Russia, for instance, before the war, class distinctions were quite marked in this way. Banks, business and professional offices, etc., opened at ten o'clock. Lunch was served at two, dinner at seven, evening tea between eleven and twelve, regular social activities continued till two or three and special social functions till four or five in the morning. The laboring classes, on the other hand, must get up early and retire early at night. Night life thus became a form of "ostentatious display."

On the whole, then, it appears that the motives which have led to the substitution of the night life for the life of the sunlight day have little or nothing to recommend them, whether we consider them in their economic, hygienic, moral, social or psychological relations. They rest upon an obsolescent social philosophy and outgrown anthropological habits. They can not prevail at a time like this when we recognize the dignity of labor, the importance of health and the need for conservation of our material resources. The daylight-saving movement is therefore distinctly a modern movement, representing just what the present age stands for, namely, health, economy, conservation and common sense.

THE SNOWFALL OF THE UNITED STATES

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The Economics of Snow

THE margin of temperature difference between rain and snow is a narrow one. It is, however, one of the most critical points in man's relation to the atmosphere, because of the fundamental differences in the economic effects of rain and snow. Snow, especially the deep snows which lie for weeks and months on the mountains and plateaus of the semi-arid West, furnish a slower and therefore a more lasting natural supply of water for power, for irrigation, and for general use than does rain, which has a quick run-off. In the drier sections of the United States many of the most important problems with which engineers have to deal, whether in connection with railroad construction and operation, or hydraulics, or irrigation, or general water-supply, are connected with the depth and conditions of snowfall, and with the amount of water which its melting will supply. In California, the mountain snowfall has well been termed the life-blood of the state, and the same is true of most of the vast territory west of the Rocky Mountains. The farmers throughout the districts of deficient precipitation are deeply concerned with the amount of winter snowfall, for the melting snows supply most of the water needed for irrigating the crops. A winter snow-cover prevents deep freezing of the ground; protects grasses and fall-sown crops, and provides spring moisture for growing vegetation.

When sufficiently deep, and more or less permanent, snow makes sleighing possible, and greatly facilitates lumbering operations over the forested sections of the northern and north-eastern states. Heavy winter snows, on the other hand, interfere with railroad operation, sometimes causing serious and expensive interruption of transportation, and involving great expense for the removal of snow from steam and electric railroads, and from city streets. At the same time, such conditions furnish employment to thousands of men. An open winter, with light snowfall, means a saving of millions of dollars to the railroads and cities in the snow-belt. In the latitudes of heavy snowfall, snow-sheds, snow-fences and snow-ploughs are essen-

tial to a reasonably uninterrupted railroad service. The demand for all kinds of rubber footwear in the states where snowfall is a common winter characteristic has given rise to one of the important manufacturing industries of the snow-belt. The use of snowshoes and of skis, for winter sports as well as for ordinary means of locomotion, is another result of a winter snow-cover.

The Measurement of Snowfall

The accurate measurement of snowfall presents many difficulties, and no reasonably simple, practical and satisfactory method for general use has yet been devised. Most of the available records are still of rather doubtful accuracy. What is needed is careful determination both of the depth of snow as it falls and also of the water-equivalent of the snow when melted. The widely-quoted average ratio of ten inches of snow to one inch of water is subject to very wide fluctuations, for it depends upon the varying density and quality of the snow. The essential difficulty in obtaining accurate measurements by means of any ordinary form of gauge results from the effect of the wind in preventing the snow from falling into the gauge. In calms, or during light winds, there is little or no error, but when there is much wind such a gauge, unless properly protected or screened in order to break the force of the wind, will give too small a catch, the deficiency becoming greater as the wind velocity increases.

In view of the economic importance of the amount of water available for irrigation and power in the western states, considerable study has been made, especially during recent years, of the whole problem of the more exact determination of the depth of snowfall and of its water-equivalent. Various improvements in snow-gauges which weigh the snow directly have been made by Marvin, Fergusson, Rotch and Fitzgerald, but there still remains the difficulty of securing an accurate catch. Professor Charles F. Marvin, the present Chief of the Weather Bureau, has devised a large shielded weighing gauge which has given fairly satisfactory results at some stations, but there have been difficulties with it on account of the blocking of the top of the collector during wet and sticky snows and by frozen snow, as well as by reason of its being crushed by the weight of very deep snow. In snows which accumulate to a depth of many feet a very large gauge becomes necessary, and there are many difficulties which are not met with where snows are light. In the regions of very heavy snowfalls on the higher unin-

habited elevations of the western states there is the difficulty of visiting the gauges during the winter, and of constructing a gauge of some sort which may catch, and record, the snowfall of a whole season. Snow "bins" of various forms, standpipes, platforms, and other devices have been tried, without much success. Various methods have also been used for measuring the depth of snow by means of snow-stakes, and of melting cross-sections of snow in order to determine the average density of the snow cover. Professor J. E. Church, Jr., of the University of Nevada, has obtained good results by using snow-stakes, and by cutting out and measuring tubular sections of the deep snows of the Sierra Nevada by means of his improved "snow sampler."[1]

In this instrument, vertical snow cylinders are cut out by means of several sections of tubing of small diameter, and the water content of this sample is determined by weight, the dial of the spring balance being graduated to indicate the depth of water instead of its weight. In order to ascertain in advance the amount of water which will each year be available from the melting mountain snows, surveys have been made of type watersheds in selected areas of the West, and the amount of snow on adjacent watersheds is then estimated. Surveys of this kind will undoubtedly be greatly extended by the Weather Bureau in the near future.

In the matter of forecasting the amount of water available from snow, the rate of melting of the snow, as well as the amount of evaporation from the snowfields and from the surfaces of water storage basins are obviously of great consequence. Some years ago (1908) Professor J. N. Le Conte devised a method for determining the mean rate of melting of the snows in the Sierra Nevada Mountains of California.[2] In order to obtain the true rate of melting, the average date at which the snow is of a certain depth is determined. The mean curve of melting is then compared with the actual curve of a given year. When the actual curve falls below the mean as a whole the season is dry, the rains are likely to be low, and travel in the mountains will probably be easy as early as July. When, on the contrary, the actual curve of melting is slower than the

[1] J. E. Church, Jr., "Snow Surveying: its Problems and their Present Phases with Reference to Mount Rose, Nevada, and Vicinity," *Proc. 2d Pan-Amer. Sci. Congr.*, Sec. II., Vol. II., 8vo, Washington, D. C., 1917, pp. 496–547 (a general discussion of the problem, with references to the literature).

[2] J. N. Le Conte, "Snowfall in the Sierra Nevada," *Bull. Sierra Club*, June, 1908.

mean, it may be inferred that the snows will last longer, and that high water will come later. This matter has been discussed by Professor A. G. McAdie, who has designed a model by means of which the actual curve of melting for a given season may be compared with the mean curve, and thus the probable date of the disappearance of the snow may be determined.[3]

Professor A. J. Henry, of the Weather Bureau, has investigated the weather conditions which may modify or control the disappearance of the snows in the High Sierras of California.[4] The most pronounced "snow flood" in the United States is that which passes annually down the Columbia River and which is due almost wholly to the melting snows on the mountains of the Columbia drainage basin. Otherwise "snow floods" are generally rare in the United States, flood conditions being usually brought about by a combination of snow-melting and of heavy rainfall. In the high Sierras, the most favorable weather conditions for the conservation of the snow-cover are low temperatures and little wind movement. When these conditions prevail, the average loss by evaporation is about three quarters of an inch per day. Relatively high temperature, active wind movement, and abundance of strong sunshine are the most favorable conditions for the conservation of a snow cover. Under these conditions, the loss of freshly fallen snow may average ten inches a day, and of old snow, three to four inches. In connection with the disappearance of snow, the influence of forests upon the rate of melting deserves more extended study than it has yet received. To cite but one illustration, it appears that in the case of the yellow pine forest near Flagstaff, Ariz., the spring rate of melting in the forest is noticeably slower than that over the adjacent grass and farm-land park area.[5] The observations of snowfall at the regular stations of the Weather Bureau are made by means of ordinary gauges, the amount of melted snow being included in the general record of "rainfall." In addition, the number of inches and tenths of inches of snowfall for each 24-hour interval is determined as

[3] A. G. McAdie, "Snowfall at Summit, Cal.," *Mo. Wea. Rev.*, Vol. 38, 1910, pp. 940–941; "Forecasting the Supply of Water for the Summer from the Depth of Snow," *ibid.*, Vol. 39, 1911, pp. 445–447; "Forecasting the Water Supply of California," *ibid.*, Vol. 41, 1913, pp. 1092–1093; "The Principles of Aerography," 8vo, Chicago and New York, 1917, pp. 226–229. See also J. N. Le Conte, *loc. cit.*

[4] Alfred J. Henry, "The Disappearance of Snow in the High Sierras of California," *Mo. Wea. Rev.*, Vol. 44, 1916, pp. 150–153.

[5] A. J. Jaenicke and M. H. Foerster, "The Influence of a Western Yellow Pine Forest on the Accumulation and Melting of Snow," *Mo. Wea. Rev.*, Vol. 43, 1915, pp. 115–124.

accurately as possible by measurements made at places where the snow is of average depth.[6]

These observations have been used as the basis of the snowfall maps of the United States hitherto published.[7]

The Mean Annual Snowfall Map of the United States

The standard snowfall map of the United States at the present time was constructed by Dr. Charles F. Brooks and originally published in England.[8]

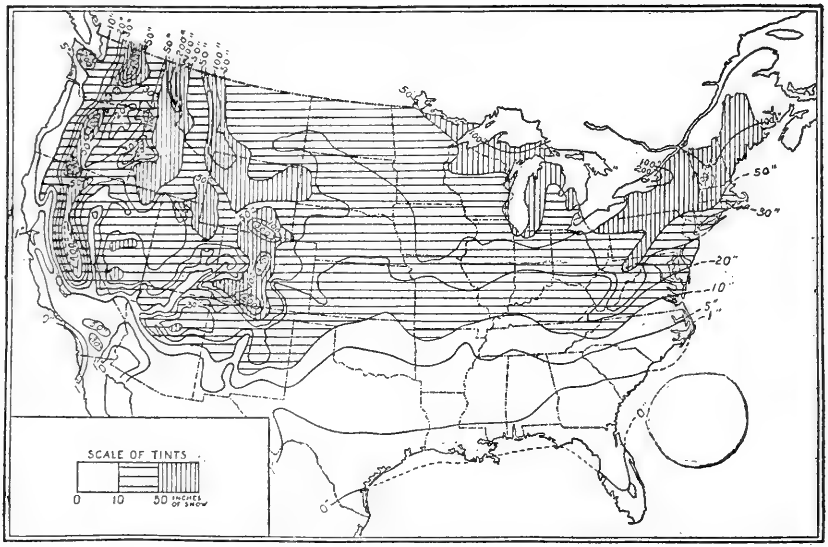
It is here reproduced, with some slight modification, for the first time. The map is based upon the snowfall observations from July, 1895, to June, 1910. In all, the data for over 2,000 stations were used. Of these, 159 had a continuous record for the fifteen years, and these were given the most weight. The data for stations with shorter records were given less and less weight as the length of the period of observation decreased. In previous maps the observations used came mostly from the larger cities, the majority of which are not far from sea-level.

[6] Current data regarding snowfall may be found in the "Annual Reports of the Chief of the Weather Bureau"; in the *Monthly Weather Review* (including the *Annual Summary*), and in the monthly and annual reports of "Climatological Data" which are issued for the section centres, each section as a rule corresponding to a state. Averages, covering periods of years, may be found in the "Summaries of Climatological Data by Sections," and in A. J. Henry: "Climatology of the United States," *Bulletin Q*, U. S. Weather Bureau, 4to, Washington, D. C., 1906. Both of the last-named publications also contain brief statements concerning snowfall in their texts. Maps showing the depth of snowfall for each month appear regularly during the winter in the *Monthly Weather Review*, and the depth of snow on the ground is charted weekly during the season in the *Snow and Ice Bulletin*. All of the above are regular publications of the Weather Bureau.

[7] The first snowfall map of the United States was constructed by Professor Mark W. Harrington on the basis of data covering the general period 1884 to 1891. A reproduction may be found in F. Waldo, "Elementary Meteorology," 8vo, New York, 1896, Fig. 108, p. 344. A later chart, for the general period 1884 to 1895, the data covering varying numbers of years from 3 to 11, by Professor A. J. Henry, was published in the *Monthly Weather Review*, Vol. 26, March, 1898, Ch. XI., Text, p. 108. A note is appended to the chart, stating that the snowfall of the Sierra Nevada and Rocky Mountains is "much greater" than is shown on the chart. Monthly charts, showing the average depth of snowfall from October to May, inclusive, based on records of varying lengths from five to twenty years, mostly not over seven years (1884–1891), were published in 1891 by Professor Harrington (*Bulletin C*, U. S. Weather Bureau, 1894, Pl. XVIII., text, pp. 16–17).

[8] Charles F. Brooks, "The Snowfall of the United States," *Quart. Journ. Roy. Met. Soc.*, Vol. 39, 1913, pp. 81–84, Pl. II.

Hence the snowfalls on the mountains and at the higher elevations generally were not indicated. In the case of the present map, the author has made use of the observations which have been obtained at the higher altitudes as well, and, taking account of the probable effect of the topography, has for the first time shown the actual conditions of snowfall over the whole country with as close an approach to accuracy as is possible with the observations which were used. When more numerous, and later data come to be taken into account, a more detailed and a more accurate map can, of course, be constructed.



MEAN ANNUAL SNOWFALL MAP OF THE UNITED STATES. (C. F. Brooks.)

The lines on the accompanying map show the average annual depth of snowfall, in inches, on the general basis of 15 years of observation. They do not, therefore, indicate the maximum or the minimum depths which have been recorded in this period; nor the depths in any single year; nor does the 0-inch line show the extreme limit to which snow has ever fallen. It must, furthermore, be remembered that the amount of snowfall varies greatly, and very irregularly, from year to year. Years of abundant snows, well exceeding the average depth, alternate irregularly with years of deficient snowfall. This variability depends on the length and the severity of the winter, and on the number and the intensity of the snowstorms.

General Controls of Snowfall; Snowstorm; 24-Hour Snowfalls

The major controls of snowfall in the United States are the temperature; the season of precipitation; the frequency and intensity of winter storms; the topography; proximity to primary sources of moisture-supply, such as the oceans and the Great Lakes, and the exposure to damp winds. The heaviest snowfall is to be expected where the winter season naturally has abundant precipitation, and where the temperatures are low enough to give snow instead of rain. Such conditions are found on certain mountains, as on the Sierra Nevada, for example, where the low temperatures are due to the altitude, or on damp lowlands, as in the vicinity of the lakes, where the climate is continental and therefore the winters are cold. The temperature control over snowfall is clearly indicated in the decrease in the amount of snow towards the south, and also along the Atlantic coast, where, during the winter months, rain frequently falls with onshore winds while it is snowing in the interior, not many miles away.

Over nearly all of the eastern United States the northeast wind, being both cold and damp, is the chief snow-bringer. A "northeast snowstorm" is a familiar winter characteristic, especially along the Atlantic coast.[9] The heaviest snows usually come in February or even in March over the northern sections. The northwest winds, blowing on the rear of the storms, are plenty cold enough to give snow, but are generally too dry. Snow flurries, rather than deep and general snows, are therefore usually associated with them. Exceptions must, however, be made in the case of windward mountain slopes, as in the Appalachian area, and of places to leeward of the Great Lakes, where the northwest winds may bring heavy snowfalls. In an intensive study of two great snowstorms, Dr. Brooks has brought out certain characteristics of snowfall distribution which are doubtless of common occurrence.[10]

Snow fell over a wide area on each side of the storm track. The heaviest snows came with northeast winds, over a belt about 100 to 200 miles in width, to the north of the track. The northwest winds, in the southwest quadrants of the storms, sprinkled light snows over the country as far as about 300 miles to the southward of the track. A distinct "patchiness" in the

[9] Charles F. Brooks, "The Snowfall of the Eastern United States," *Mo. Wea. Rev.*, Vol. 43, 1915, pp. 2–11.

[10] Charles F. Brooks, "The Distribution of Snowfall in Cyclones of the Eastern United States," *Mo. Wea. Rev.*, Vol. 42, 1914, pp. 318–330; Chs. 11.

distribution of these snowfalls resulted from local topographic features.

It is a general characteristic of heavy snowfalls in eastern districts, especially on mountains, that they are accompanied by fairly high winds. A marked contrast to this condition is found in the region of very deep snows on the Sierra Nevada Mountains of California, for example, where the winds are always relatively light.

The greatest 24-hour snowfalls in the different sections of the country have been summarized by Professor Henry as follows: northeast, 2–3 ft.; elsewhere east of the Mississippi River, from 8 inches (Ohio Valley) to 18–20 inches (along the Lower Lakes); southern states, 4–8 inches; Mississippi Valley, 5 inches (Vicksburg) to 20 inches (St. Louis); northern plains, 9–17 inches; Rocky Mountains, 8–24 inches; Plateau and Northern Pacific coast, 10–20 inches.[11]

General Distribution of Snowfall in the United States

Snow falls regularly every winter over by far the greater part of the United States. The only sections which seem to be exempt from even occasional snowfalls are southern Florida and the lowlands of southernmost California adjacent to the ocean. There is considerable variation in the latitudes which mark the southernmost limits of snowfall in any given winter, but for purposes of convenience and of easy memorizing, the limiting latitudes of regular and of occasional snowfall may be broadly generalized as follows:

Latitudes of Regular and of Occasional Snowfall

District	Regular	Occasional
Pacific Coast..	45° (northern Oregon)	34° (Los Angeles)
Interior	30° (northern Gulf)	26° (southeast Texas)
Atlantic Coast..	35° (Hatteras)	29° (northern Gulf)

From a practical point of view it may be said that snow does not occur in sufficient amount to lie unmelted on the ground south of San Francisco on the lowlands of the Pacific Coast, or south of Cape Hatteras on the Atlantic Coast. This statement, however, does not hold for inland districts, or for elevated areas. The southern boundary of a regular winter snow-cover, in ordinary winters, may be put at about lats. 41°–42° in the eastern United States, but occasional winters carry the snow-cover a good deal farther south. It is one of the marked climatic characteristics of the eastern United States that snow not infre-

[11] *Loc. cit.*, footnote 6, pp. 58–59.

quently occurs unusually far south, in districts which have very mild winters.

The most striking general facts on the snowfall map are the effects of the topography in causing very heavy snowfalls on the western flanks of the Sierra Nevada and Cascade Ranges (exceeding 400 inches over considerable areas); the "snow-shadow" effect of this western mountain barrier in causing a decrease in the depths of snowfall over the interior plateau districts as a whole, with larger amounts over the mountains and higher plateaus; the heavy snows of the Rocky Mountain system, averaging considerably less than on the Pacific Coast mountains, but amounting to more than 100 inches over fairly large areas even as far south as northern New Mexico, reaching over 300 inches in southern Wyoming and 400 inches in parts of the Colorado Rockies. East of the Continental Divide the snowfall rapidly decreases again, the lines of equal depth extending in a general east-and-west direction under the control of latitude. The Appalachian mountains and plateaus carry the lines well to the south (50–100 inches from Maine to Maryland), while the warm waters of the Gulf Stream carry them northward along the coast as far as Cape Hatteras. In the vicinity of the Great Lakes, especially on their lee shores, and thence eastward along the Canadian boundary as far as New England, there is a relatively heavy snowfall (more than 100 inches in northern New England and 80 to more than 100 inches on the lee shores of the lakes). Including the higher altitudes, the annual snowfall may be said to average roughly more than 20 inches over northern and less than 20 inches over southern sections. Most of this snow falls from December to March, but at the higher elevations, and in the northern states, it begins as early as October or even September, and falls as late as April or even May. In general, topography is seen to be the most striking control in the west, and latitude in the east.

The Snowfall of the Pacific Slope

The snowfall over the lowlands of the Pacific Slope is of little importance. It is very light, even in the north, and seldom excites interest except when, at long intervals, snow falls in southern districts where it is so uncommon as to be a curiosity, or when, occasionally, a heavier fall than usual in the northern districts causes comment. Snow is rare on the immediate coast south of the northern boundary of California (latitude 42° N.), but it is frequent on the mountains, even in southern California.

When snow does occur on the lower lands of southern California, it seems always to fall with hail, sleet or rain.

Interest is, however, naturally very great in what has for years enjoyed the distinction of being the area of heaviest snowfall in the United States. This area, which is clearly indicated on the snowfall map, is on the western slopes of the high Sierras of California, and has been closely studied along the line of the Southern Pacific Railroad which connects Sacramento, Cal., and Reno, Nev. Recent discussions by Professor A. G. McAdie[12] and Andrew H. Palmer[13] have brought out many interesting facts regarding this remarkable snowfall.

Over an elongated area of considerable extent stretching along the windward (western) upper slopes of the mountains, the average annual snowfall is over 400 inches, *i. e.*, over 30 feet deep. Another area, also with over 400 inches, is found over the Cascade Mountains in northern Washington, but has not yet been intensively studied. The average annual snowfall at Summit, Cal. (7,017 ft.), for 44 years, is 419.6 inches, and the average for 8 years at Tamarack (8,000 ft.) is 521.3 inches. During the winter of 1879–80, 783 inches of snow fell at Summit, and in 1889–90, 776 inches. At Tamarack, in 1910–11, 757 inches fell. The depth on the ground (9-year average) has been determined as follows (T, Tamarack; S, Summit):

INCHES

	Dec. 1	Jan. 1	Feb. 1	Mar. 1	Mar. 15	Mar. 31
T	19	62	165	183	194	192
S	9	44	122	127	140	118

The total precipitation as rain and melted snow is 48.1 inches at Summit and 57.5 inches at Tamarack. These totals by no means represent a very heavy annual precipitation. The significant fact is the proportion of the whole which falls as snow. The Pacific Slope has dry summers and a well-marked winter maximum of precipitation. This maximum results from a combination of various factors, among which the more important are the general winter storms and the prevalence of moisture-laden onshore winds which, in ascending the then cold slopes of the higher mountains, are cooled to temperatures below freezing. This winter maximum is very distinct over the lowlands and valleys, but is less marked at the higher levels. The increase in annual precipitation with increase of altitude, which

[12] See footnote 3.

[13] Andrew H. Palmer, "The Region of Greatest Snowfall in the United States," *Mo. Wea. Rev.*, Vol. 43, 1915, pp. 217–220, with illustrations.

is a general characteristic of mountains, is rapid up to a certain height, after which the rate lessens, and finally there is a decrease in precipitation with altitude. A maximum amount of rainfall, including melted snow, is reached at between 6,000 and 7,000 feet.

Railroad operation in this region shows many responses to the heavy snowfall, as all travellers over the Southern Pacific route, through Summit, well know. The famous "thirty miles of snowsheds" cost $42,000 a mile over single track and $65,000 over double track. About $150,000 is spent annually for upkeep and renewals. The life of a shed averages a little over twenty years. Fire-fighting trains are kept always in readiness in case the sheds take fire, which they often do. The weight of the snow is so great that sections of the sheds occasionally collapse. A heavy rain and snow gauge has been completely crushed by the snow, and a fence made of two-inch boiler flues has been bent. The gables of the houses are all built at sharp angles, so that the snow may slide off. Some very recent observations on Mt. Rainier, Wash., indicate that the snowfall in that district is extraordinarily heavy.[14] Daily records of snowfall were kept during most of the season of 1916–17 at Paradise Inn, on the south slope of Mt. Rainier, at an elevation of 5,500 feet. Observations were not begun until November 24, 1916, but from that date until the last snowstorm before midsummer, 1917, the total depth of snowfall was 789.5 inches. The record at Paradise Inn is the first which has been obtained west of the summit of the Cascades in Washington at so great an elevation. The railroads cross the mountains at comparatively low levels. The season of 1916–17 does not appear to have been one of unusually heavy snowfall, nor is Paradise Inn located at what would theoretically seem to be the region most favorable for a maximum precipitation. It is not unlikely, therefore, that still deeper snows will eventually be recorded at greater altitudes than 5,500 feet on Rainier, which may some day deprive the Sierra Nevada of California of the distinction of having the greatest snowfall in the United States.

The importance of the water-supply from the melting snows of the higher mountains on the Pacific Slope cannot be overestimated. Millions of dollars' worth of water, for irrigation, for power, and for general city and domestic use, are obtained each year from these snows. Without them, most of the valleys and lowlands on the coast would be unable to support their

[14] Lawrence Foster, "Snowfall on Mt. Rainier," *Mo. Wea. Rev.*, Vol. 46, 1918, pp. 327–330.

present crops, and the population of the region would never have attained its present numbers.

Snowfall over the Western Plateau Region

Over the western plateau area, between the Sierra Nevada-Cascade ranges on the west and the Continental Divide of the Rocky Mountains on the east, most of the winter precipitation comes in the form of snow. The essential features of the snowfall distribution are the general decrease over the valleys and less elevated portions from 20 to 30 inches in the north to less than 5 inches and even to 0 inches in the south. Over these districts of light snowfall the ground usually does not remain covered many days at a time, and in the region of the lower Colorado River, in southwestern Arizona and southeastern California, snow is rarely seen except on the mountains. The mountains and more elevated plateaus have decidedly heavier snows. A maximum of over 400 inches is reached in some parts of Colorado; of 300 inches in southern Wyoming, and of over 100 inches in many places from Idaho and Montana on the north to northern New Mexico on the south. The snowfall in the Colorado mountains is much greater than the summer rainfall, and comes largely in the spring months. Most of the rivers of the plateau states have their sources in the higher mountains, and the slow melting of the snows, which usually last well into the summer, supplies these streams with water which is essential for irrigation. The maximum stream-flow ordinarily comes in late spring or early summer, when the melting of the mountain snows is most rapid. It is a saying among the Indians of Arizona that when the last snow disappears from the mountain tops, the late summer rains are about to begin.

Snowfall on the Great Plains

Lying to leeward of the Rocky Mountains, and being far from any considerable source of water vapor, the plains inevitably have relatively little snowfall. Their total annual precipitation is less than 20 inches, and most of this falls in summer. Thus winter is a dry season, and the snowfall which it brings is light. Even in the extreme north, where the winters are very cold and practically all the precipitation of the five or six colder months is in the form of snow, the average annual snowfall is under 50 inches. The winter storms do not, as a rule, give much snow. Even the "blizzards" are not usually accompanied by heavy snows. They are dangerous to cattle, and occasionally

to human beings, because of the bitter cold of their northerly winds, and because these same winds carry fine ice spicules and are also filled with blowing snow which makes it difficult or impossible to see. Severe blizzards are, as a matter of fact, not as common as most people think. A whole winter sometimes passes without a typical blizzard.

Over the southern plains, owing to the warmer winters, the snowfall decreases to less than 10 inches, and even to less than 5 inches in western Texas and southern New Mexico. The number of days with snowfall also decreases, from an average of 40 or 50 in the north to 5 or 10 in Oklahoma, and to less than 5 in extreme southwestern Texas.

It is a characteristic of the snowfall over the northern plains that most of it falls at temperatures well below freezing. For this reason it is light and dry, and is easily carried by the strong winds, which blow it into ravines and other depressions, leaving the ranges for the most part bare and accessible for grazing. In the south, the snow soon melts under the warm sun.

Over the mountains which border or interrupt the plains, it snows more frequently and during a longer season. The melting of these deeper snows furnishes much of the water which is used for irrigation along the rivers flowing to the eastward towards the Mississippi.

Snowfall of the Eastern United States

In the eastern half of the country, the dominant control over snowfall is latitude, as is evidenced by the general east and west trend of the lines of equal depth of snow on the map. Subordinate, but nevertheless important controls are found in the effects of topography (Appalachians, Adirondacks, White Mts. of New Hampshire); of the frequency of cold, damp storm winds (Great Lakes and northeastern sections), and of the warm waters of the Gulf Stream (southern Atlantic coast). The depth of snow decreases to the west of the lakes because winter is there a relatively dry season, and to the south because of the higher temperatures. A detailed study of the snowfall of the eastern United States has been made by Dr. Charles F. Brooks.[15] This shows clearly the local modifications which re-

[15] Charles F. Brooks, "The Snowfall of the Eastern United States," *Mo. Wea. Rev.*, Vol. 43, 1915, pp. 2–11. Includes original charts showing the average depths of snowfall by months, from September to May; the average annual snowfall (1895–1913); the average annual number of days with snowfall; the mean annual, maximum and minimum annual, and extreme annual range of snowfall about the Great Lakes, for the period 1895–1910; also monthly charts showing the directions of the snow-bearing winds.

sult from the topography and from exposure to damp winds. More snow is seen to fall on the western than on the eastern slopes of the Appalachians, except in Vermont.

Over the northern tier of states in the eastern half of the country snow is a factor of considerable economic importance, especially over northeastern sections where the depths are greatest. Sleighing is often possible for weeks at a time in winters of abundant snowfall, the depth of snow on the ground reaching two or three feet in certain sections. Such snows greatly facilitate the lumbering industry by making it possible to use heavy sledges for hauling the logs out of the forests. "Open winters," on the other hand, make lumbering difficult and expensive. Warm winter rains are especially characteristic of the Atlantic coast sections and naturally occur with increasing frequency toward the south, quickly melting any snow which happens to be lying on the ground. In the spring months, heavy rains of this type, or unseasonably high temperatures unaccompanied by rains, not infrequently cause a very rapid melting of the deeper snows lying in the mountains, and produce freshets and floods in the Ohio and other river systems of the northeast.

The season of snowfall over northern sections is a long one. Snow in measurable amounts may fall as early as October, or even in September in the White Mountains of New Hampshire and in the Adirondacks, and as late as May. Indeed, snowstorms of considerable intensity have occurred in April, but the heaviest snowfalls usually come in February, or at times early in March. The general snow-cover advances as a whole from north to south with the advance of winter, very irregularly and often with many retrogressions as well, its southern margin being uneven and broken under the control of varying conditions of topography, storm control and temperature. It usually reaches its southermost limits in January or in February, and then retreats northward again. This seasonal advance and retreat, with its many irregularities, can be studied to advantage on the *Ice and Snow Bulletins* of the Weather Bureau.

Towards the south, as latitudes of milder winters are reached, the season during which snow may fall becomes shorter and shorter. Less and less of the precipitation of the colder months falls as snow, and more and more comes in the form of snow and rain mixed, and then of rain. The number of days with snowfall decreases. Thus, while days with snowfall average over fifty a year over most of the Lake region and St. Lawrence Valley, including northern New England, there is an

average of only one day with snowfall along a line reaching from southeastern North Carolina to south of Vicksburg, Miss. (fifteen years). The mountainous section of all the southern states which are crossed by the Appalachians have more days with snowfall, and more snow than the surrounding lowlands and valleys. There are, for example, fifty days with snowfall a year as far south as Elkins, W. Va., but the accumulation of snow is not sufficiently great to be a factor in causing dangerous spring floods as is the case farther north. With decreasing latitude, snow lies on the ground less and less of the time, and soon becomes an almost, and then an entirely, negligible factor. When it falls over much of the South, it is merely a matter of temporary discomfort, melting soon. Southern South Carolina is practically exempt from snowfall. In Georgia, snow, when it falls, melts almost immediately, although it may remain on the ground a few days in sheltered places in northern sections of the state. It is not an uncommon occurrence for a season to pass without snow enough to cover the ground over the northern portions of the northern gulf coast states. Farther inland, as, *e. g.*, in Tennessee, the ground is rarely covered more than a very few days at a time, but unusually heavy snowstorms, at long intervals, may result in a snow-cover which lasts a week, or even more.

Over the sections immediately adjacent to the Gulf of Mexico, snow becomes practically negligible. Occasionally, at long intervals, there are measurable amounts in northern and even central Florida. The gulf sections of Alabama, Mississippi and Louisiana have a 15-year average of less than one inch, and an average of less than 1 day with snowfall annually. Years may go by without any snow along the Texas coast and in the lower Rio Grande Valley. Much interest attaches to the occasional occurrence of unusual snowfalls in the south. During spells of exceptional cold, snow may fall to the depth of a good many inches at various localities along the southern Atlantic and Gulf coasts, and with diminishing depth even as far as extreme southeastern Texas. On such occasions, thousands of people witness their first snowstorm.

Sleet and Ice Storms

Sleet and ice storms are so closely associated with snowstorms in the eastern United States that it is often difficult to forecast snow because a storm of sleet or ice may occur instead. According to the present Weather Bureau definition, sleet is precipitation that occurs in the form of frozen or partly frozen

rain. It is formed by rain falling through a relatively warm stratum into or through another stratum which is cold enough to freeze some or all of the rain drops. When, under these general conditions, rain drops fall to the earth's surface and freeze on coming in contact with solid objects on that surface, an ice-storm results. Telegraph, telephone and trolley wires, trees, sidewalks and streets are then covered with an icy coating. Service is thus often interrupted because of broken wires, and transportation becomes difficult or dangerous by reason of slippery rails and streets. Considerable damage is often done to forest and fruit trees by such ice-storms. Mr. Verne Rhoades, of the U. S. Forest Service, has called attention to the wide-spread damage caused by a single ice-storm in the southern Appalachians,[16] and Mr. W. W. Ashe, Forest Inspector of the Forest Service, has pointed out that the damage done by these storms is such that the dates of past ice-storms may be determined by an examination of the trees. In the case of trees damaged by a recent ice-storm along the Blue Ridge Mts., in Amherst Co., Va., evidence was found of injury by two previous storms, about 14 and 35 years, respectively, before the last one.[17] Professor H. C. Frankenfield, of the Weather Bureau, has recently made a study of sleet and ice storms in the United States.[18]

The region of maximum frequency is over a broad central belt reaching from west of the Mississippi eastward and northeastward to the Atlantic. This is, in general, the portion of the country which is crossed by the principal storm areas, with their cold northerly winds to the north and warm southerly winds on the south of their centers. These conditions are essential to sleet formation. Severe sleet storms may occur from November to March, inclusive, and occasionally in April and October to the north of the 42d parallel. It appears that steep northward temperature gradients, and high temperatures over the Gulf and South Atlantic States are necessary for sleet formation, and are usually absent before and during heavy snows. Surface temperatures preceding sleet and ice storms are below freezing, usually between 22° and 28°, and the high

[16] Verne Rhoades, "Ice Storms in the Southern Appalachians," *Mo. Wea. Rev.*, Vol. 46, 1918, pp. 373–374.

[18] H. C. Frankenfield, "Sleet and Ice Storms in the United States," *Proc. 2d Pan. Amer. Sci. Congr.*, Vol. 2, Section 2; Astronomy, Meteorology, and Seismology, pp. 249–257 (discussion, pp. 252–257). Washington, D. C., 1917. (Gives a map showing the average annual frequency of sleet and ice storms, and typical weather maps favorable for their occurrence.)

[17] *Ibid.*

temperatures in the south which precede the sleet are accompanied by southeasterly to southerly winds.

The ice-storms of New England have been discussed in some detail by Brooks,[19] who has based his study chiefly on the very complete records obtained at Blue Hill Observatory, Mass., and has included a consideration of upper-air conditions. Three general types of wind conditions produce ice-storms. These are (1) warm air arriving over residual cold air ("southerly" type); (2) cold air coming in below and warm air arriving above ("northeasterly" type); (3) cold air pushing in from the north or west below a rain cloud ("northwesterly" type). Classifying ice-storms according to the positions and movements of the low and high pressure conditions (cyclones and anticyclones) which produced them, there are seen to be two large groups. The first includes storms with anticyclones in the north dominating southern cyclones, and the second includes those in which the cyclones and anticyclones were in regular sequence.

Is Snowfall Decreasing?

There is a widespread popular belief in many parts of the country, especially in the earlier settled sections of the northeast, that less snow falls now than was the case years ago. In New England, for example, it is customary to speak of the "old-fashioned New England winters" which brought many heavy snowstorms; when snow lay on the ground uninterruptedly all winter, and when sleighing was possible for three or four months without a break. In a question of this kind it is, of course, impossible, to put any confidence in general impressions or in tradition. It is a mistake to place absolute trust in our memories, and attempt to judge such subtle things as differences in snowfall on the basis of such memories, which are at best short, defective, and in the highest degree untrustworthy. The tendency inevitably is to exaggerate past events; to remember a few exceptional seasons which, for one reason or another, made a deep impression on us, and very much to overrate some special event. Individual severe winters which, as they occur, are some years apart, seem, when looked back upon from a distance of several years later, to have been close together. It is much as in the case of the telegraph poles along a railroad track. When we are near the individual poles, they seem fairly far

[19] Charles F. Brooks, "The Ice Storms of New England," *Annals Astron. Obsy. Harv. Coll.*, Vol. 73, Pt. 1, 4to, Cambridge, Mass., 1914, pp. 8, pls. 2 (Abstract in *Mo. Wea. Rev.*, Vol. 42, 1914, pp. 455–457); "Three Ice Storms," *Science*, Aug. 8, 1913, pp. 193–194.

apart, but when we look down the track, the poles seem to stand close together. The difference in the impressions upon youthful and adult minds may account for part of this popular belief in changes of climate. To a youthful mind a heavy snowstorm is a memorable thing. It makes a deep impression, which lasts long and which, in later years, when snowstorms are just as heavy, seems to dwarf the recent storms in comparison with the older.

Changes of residence may account for some of the prevailing ideas about changes of climate. One who was brought up as a child in the country, where snow drifts deep and where roads are not quickly broken out, and who later removes to a city, where the temperatures are slightly higher, where the houses are warmer, and where the snow is quickly removed from the streets, naturally thinks that the winters are milder or less snowy than when he was a child.

The only reliable evidence is that which rests upon instrumental records. Accurate instruments, properly exposed and carefully read, do not lie; do not forget; are not prejudiced. When such instrumental records, scattered though they are, and difficult as it is to draw general conclusions from them, are carefully examined, from the time when they were first kept in this country, which in a few cases goes back a century or more, there is found no evidence of any progressive change in the amount of snowfall. Some winters now bring deeper snows and greater cold, while others are mild and "open." These variations result from differences in the numbers, intensity and paths of winter storms, as is clearly seen by a study of the daily weather maps. This same sort of variability was characteristic of the past, and will continue forever. In other words, a mild winter with light snowfall is just as "old-fashioned" as one with severe cold and heavy snowfall. There were plenty of both kinds of winters in the past. There will be plenty of both kinds in the future.

In his "Climatology of the United States," which was a standard publication in its day (1857), Lorin Blodget, in a chapter on the "Permanence of the Principal Conditions of Climate," speaking of the evidence for and against climatic change, held that "real history would be more valuable than anything else if it could be relied on, but there is great looseness with much exaggeration in everything dating back beyond the use of instruments." Blodget believed that "the Northmen found the New England coast 860 years ago quite precisely the

same in climate as now—wild vines growing in a very few of the most favored spots, and only in these."

Dr. Hugh Williamson is quoted as saying, in 1770, that the winters of the last half-century had been milder than formerly, and Professor Samuel Williams, of Harvard College, whose lectures were among the foundation-stones of American meteorology, asserted that "the winter is less severe, cold weather does not come on so soon." These views sound singularly like those which are heard expressed nowadays. It so happens that the early settlers of New England made a special point of keeping a chronicle of weather conditions, so that we have a record of the character of the seasons running back over three centuries. When these old accounts are examined, it at once becomes apparent that New England had precisely the same variability in its winters in the earlier days of its settlement as now. There are accounts of great cold; of deep snows; of violent winter storms. There are also many descriptions of very mild and open winters. Thus, we read of December and January resembling May and June; of flowers growing in the woods in midwinter; of so little snowfall "as scarcely to give opportunity for enjoying the music of the sleigh-bells"; of "green Christmases"; of "winter turned into summer"; of the "ground bare for the most part"; of little ice; of crocuses up, of wild violets in bloom, and of lilacs "throwing out their leaves" in January.

It has been well pointed out that if a list were compiled of heavy snowstorms, of droughts, of floods, of severe cold, of mild winters, of heavy rains, and of other similar meteorological phenomena, for one of the early-settled portions of the United States, beginning with the date of the first white settlements and extending down to the present day, we should have the following situation. Dividing this list into halves, each division containing the same number of years, it would be found, speaking in general terms, that for every mild winter in the first half there would be a mild winter in the second; for every long-continued drought in the first division there would be a similar drought in the second; for every "old-fashioned" winter in the first group there would be an "old-fashioned" winter in the second. And so on, through the list. In other words, weather and climate have not changed from the time of the landing of the Pilgrims down to the present day.

THE ORIGINS OF CIVILIZATION—II

By Professor JAMES HENRY BREASTED

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THE evidence for the possession of domestic animals is not as old as that for agriculture. The bodies from the earliest Egyptian cemeteries contain fragments of bones of mammals, but there is no way to prove that these necessarily small fragments belonged to *domesticated* mammals. Nevertheless, the results of long continued selective breeding demonstrate the remote origin of domestic animals in the Nile valley. At the same time the monuments reveal the Egyptians as persistently practising domestication far down in the historic age.

Pre-dynastic reliefs (Fig. 24) to be dated not later than the middle of the fourth millennium B.C., already show us three of the commonest domestic animals, the donkey, sheep and cattle. The domesticated donkey of Egypt was long ago demonstrated by Schweinfurth and others to have had its original home in northeast Africa and to have been domesticated on the Nile. Its wild ancestor, *Asinus tæniopus,* or the steppe ass, is still found as far north as the mountains of southern Nubia.[18]

The sheep shown in this carving still display primitive characteristics, carried over into the domesticated state, *e. g.,* standing ears and a mane, and the female with horns, which she later lost. They have been identified as *Ovis longipes palæoægypticus* by Duerst and Gaillard. Their nearest relatives, as both these two scientists admit, are still scattered over north and northeast Africa to-day. It is the more remarkable that these two paleontologists would draw this sheep from Asia. Lortet, on the basis of far more material, states that this sheep (*Ovis longipes pal.*) with transverse horns, spirally twisted, has so many and so widely distributed relatives in north Africa, that he must be considered as indigenous there.[19]

Regarding the large cattle shown here the paleontologists have differed widely, with perhaps a majority maintaining his Asiatic origin, due to the fact that they were unable to find an unmistakable wild ancestor in Africa. His alleged Asiatic origin has been commonly asserted in popular books, coupled with such a remote date for his domestication, and his intro-

[18] Schweinfurth, *Zeitschr. f. Ethn.*, 44, 1912, pp. 653–654.

[19] Lortet-Gaillard, "La Faune Momifiée de l'ancienne Egypte," Lyons, 1905, p. 100.

duction into Egypt by some mysterious and unidentifiable immigrants alleged to have brought in Egyptian civilization from Asia, that we now find a widely circulating popular statement, to the effect that the Asiatic origin of Egyptian domestic animals has demonstrated the Asiatic origin of Egyptian civilization.

Both the monuments and the still largely unexplored Pleistocene strata of Egypt contain much evidence on this question.

FIG. 24. EGYPTIAN RELIEF CARVED IN SLATE, DATING ABOUT THE MIDDLE OF THE FOURTH MILLENNIUM, B.C. Showing domesticated sheep (below), donkeys (middle), and cattle (above), captured from the Libyans. Now in the National Museum at Cairo.

It quickly disposes of the Asiatic origin of these long-horned cattle. Much inscriptional evidence has shown that the Egyptians practised the hunting of wild cattle, but a relief in Benihasan which shows these cattle as spotted has led to the conclusion that such alleged wild cattle were really domestic breeds which had escaped from captivity and were running wild. The discovery of a relief of the Pyramid Age showing a hunting enclosure (Fig. 25) filled with game to be brought down by the royal arrows, has effectually disposed of this conclusion. Among the game entrapped in the enclosure we find a cow, a

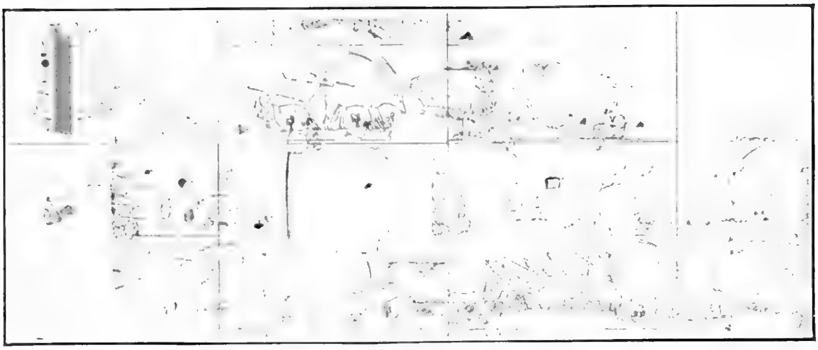


FIG. 25. ANCIENT EGYPTIAN RELIEF SHOWING A ROYAL HUNTING ENCLOSURE FILLED WITH WOUNDED ANIMALS. From the pyramid temple of Sahure, middle of the 28th century B.C. (After Borchardt.)

calf and a bull, all of a red brown color with a lighter saddle. These are unquestionably long-horned wild cattle, identified by Hilzheimer as *Bos africanus.* Pleistocene wild cattle have been proven to have existed in Algiers, and this evidence is now supplemented by the discovery of the fragment of a head of *Bos primigenius* in the Nile valley, in the Pleistocene deposits of the Fayum. The presence of the Urus thus demonstrated in Egypt has led Hilzheimer to recognize the wild cattle in this hunting scene also as the *Bos primigenius.* In any case it is totally gratuitous to identify any longer the long-horned cattle of Egypt with an Asiatic species.

It is very instructive in this connection to notice that the Egyptian continued his efforts at domestication on a wide range of wild creatures, far down into the historic epoch. In the scene under discussion (Fig. 25), dating from the middle of the twenty-eighth century B.C., we see the enclosure, which has been well said to be of itself a long step toward domestication. Here have been caught the deer, the gazelle, the oryx, the addax, and two varieties of goat. Of the leading Egyptian antilopes only the ibex is lacking. The practice of capturing these animals in an enclosure evidently very early showed the Egyptian that he might in this way maintain a store of meat on the hoof from which he could conveniently draw at will. In this way, for example, the Tschuktchi of northeast Asia maintain herds of half-domesticated reindeer, which they employ only as sources of flesh and skin clothing. These wild creatures taken out of such enclosures alive were then stall-fed and partially if not wholly domesticated. We see them in the tomb reliefs between 3000 and 2500 B.C. (*e. g.*, Fig. 26), along with the long-horned *Bos africanus*, tied to their mangers and feeding. Here are the goat (*Hircus mambrinus*), the gazelle (*Ga-*

zella dorcas), the addax (*Addax nasomaculata*), the oryx (*Oryx leucoryx*) and remarkably enough, the hyena (*Hyæna striata*).

The inscriptions confirm these relief pictures very conclusively. A mortuary text of the Middle Kingdom (around 2000 B.C.) mentions "ibexes which eat grain." Similarly already in the twenty-seventh century B.C., the tomb of Kegemni mentions "stables of the plateau antilopes" (Fig. 27). There were thus "stables" for these creatures, parallel with the stables for the large cattle, and designated by the same word. It is of course a scene from one of these stables which shows these animals eating at their mangers (Fig. 26).

These animals therefore formed a staple source of the food supply and we find them in process of being slaughtered for food, precisely as is done with the large cattle (Fig. 28). Hence at an inspection of the cattle of an estate, these creatures which we have never thought of as domesticated, duly appear together with the long-horn cattle familiar to us as domestic animals (Fig. 29).

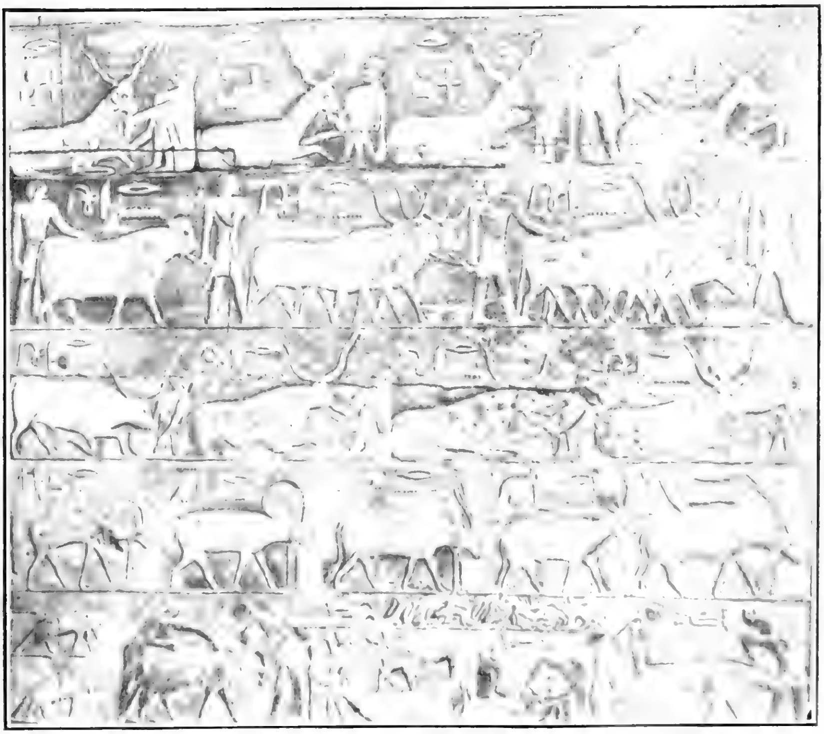


FIG. 26. STALL FEEDING OF SEMI-DOMESTICATED ANTILOPES (FIVE VARIETIES) AND HYENAS, ALONG WITH CATTLE. Relief scene in the tomb of Mereruka at Sakkara, Egypt, 27th century B.C.

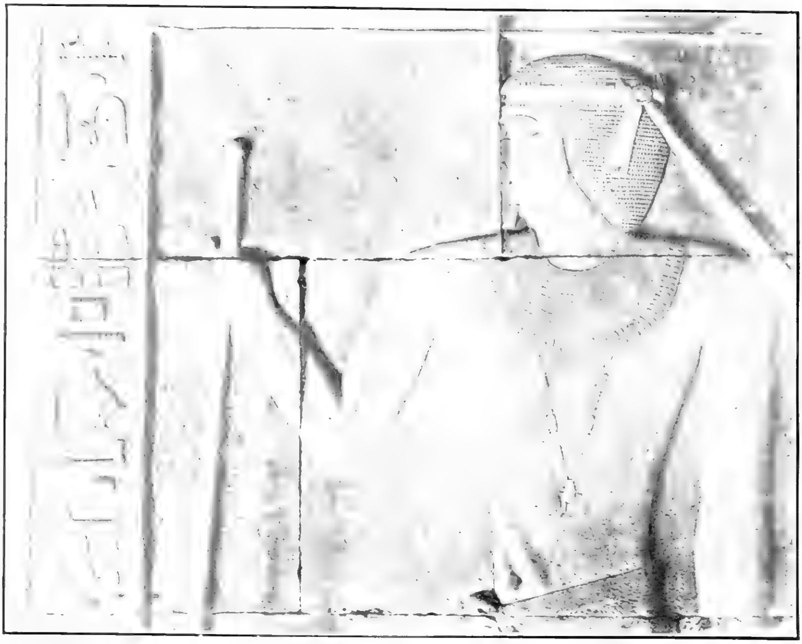


FIG. 27. PORTRAIT OF A GREAT LORD OF THE PYRAMID AGE NAMED KEGEMNI. Accompanied by his titles as "Chief of the Stables of Cattle and Chief of the Stables of the Plateau Antilopes." Relief in his tomb at Sakkara, Egypt. 26th or 27th century B.C.

In the same way, after domesticating varieties of the goose and duck, the Egyptians captured a varied list of wild fowl which they wholly or partially domesticated, although this list did not include our barnyard fowl, which was introduced in the west from India from the seventh century B.C. onward. It will be seen, then, how widely extended and inclusive was the effort of the Egyptians at domestication. They were still continuing the task in historic times, and it went on throughout the third millennium, if not much later.

It is evident from the conditions among their domestic cattle, furthermore, that they had long been engaged in the process of

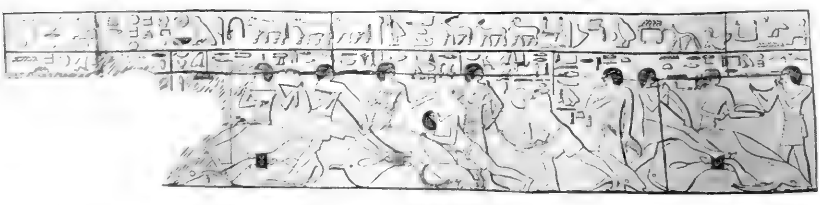


FIG. 28. BUTCHERING OF SEMI-DOMESTICATED ANTILOPES, SHOWN IN THE TOMB OF KEGEMNI. Compare Fig. 29.

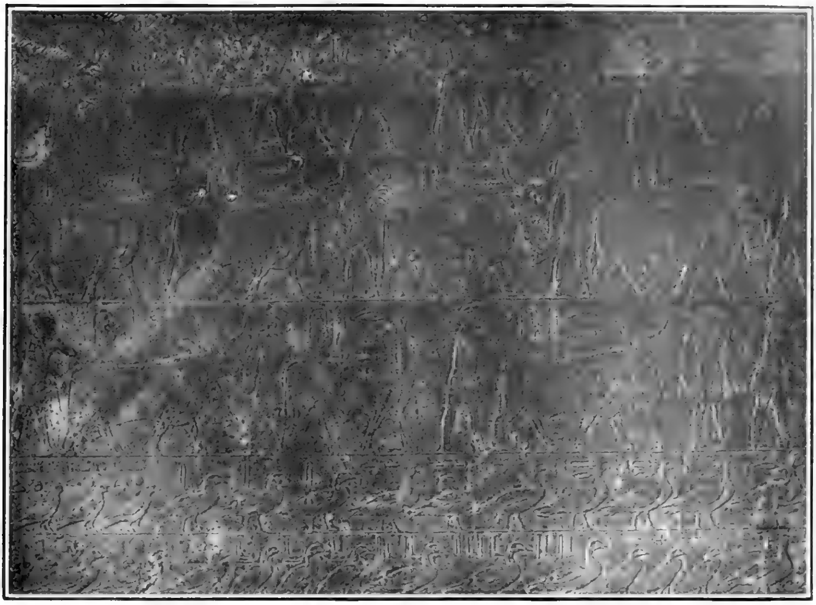


FIG. 29. CATTLE INSPECTION INCLUDING SEMI-DOMESTICATED ANTILOPES ALONG WITH DOMESTICATED CATTLE. As shown in reliefs from the tomb of Manofer, now in the Berlin Museum (27th century B.C.).

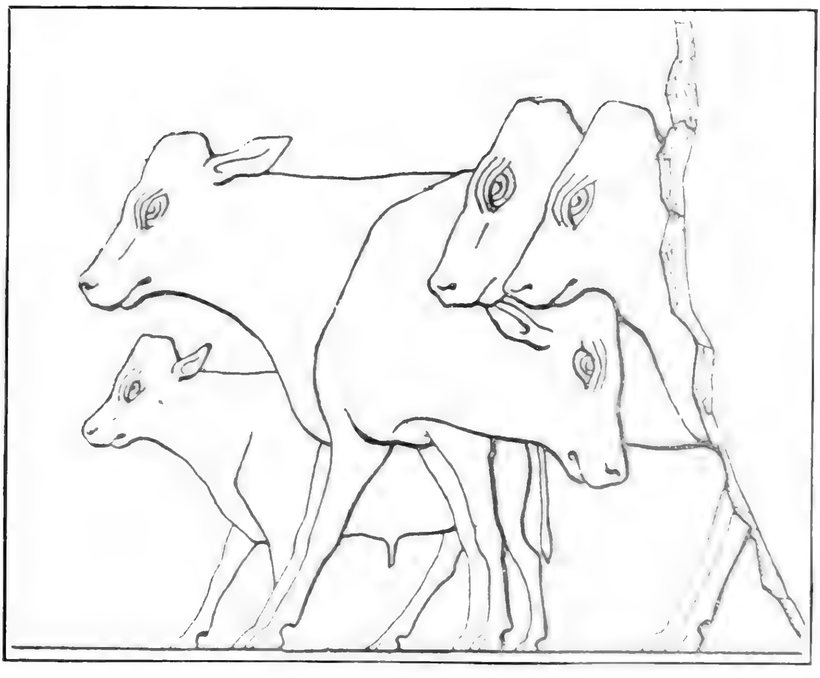


FIG. 30. HORNLESS BREED OF EGYPTIAN CATTLE. From a tomb relief at Gizeh, 29th century B.C.

FIG. 31. SKULL OF A HORNLESS BREED OF ANCIENT EGYPTIAN CATTLE. Taken from an XIth Dynasty tomb (2160–2000 B.C.). (After Lortet and Gaillard, "Faune momifiée.")

breeding. For not only had they early developed a short-horn variety out of the long-horn, which was not identical with the Asiatic short-horn (*Bos brachyceros*), but at the same time they also bred a hornless variety of cattle (Fig. 30) (*Bos akeratos*). The actual skulls of this hornless breed have survived (Fig. 31).

A series examined by Lortet led him, like Duerst, to conclude that this hornless breed of cattle was the result of long and persistent selective breeding, very intelligently carried on. In this case we would have here a situation like that which we found in the case of the domesticated grains. Wheat with ages of selective cultivation behind it, has been found in the earliest known graves in the world. Similarly the oldest domesticated herds known to modern science, that is the oldest cattle in the world, would, according to Lortet and Duerst, already include a hornless breed produced by long-continued selective propagation.

On the other hand Professor Charles B. Davenport, director of the Department of Experimental Evolution of the Carnegie Institution, has kindly informed me that "hornlessness in cattle has probably arisen many times as a sport or mutation," and might then be continued and perpetuated by selective breeding. He concludes that the hornless breed of ancient Egypt arose and was continued in this way. In either case intelligently practised cattle-breeding on the part of the Nile dwellers at a very early date is evident.

We can understand therefore, that the production of milk-producing cattle was the result of long-continued and intelligently directed selective breeding, already completed by 3000 B.C. That the milk breed had not yet become wholly accustomed to the artificial abstraction of milk by the hand of man is evident from the fact that in practically all such dairy scenes, the hind legs of the cow have been elaborately tied (Fig. 32). It is perhaps of importance to note also that the calf is kept in the vicinity, and its eagerness for maternal food is restrained by another herdsman while the milking process goes on.

It is thus evident that conditions both in agriculture and cattle breeding in the Nile valley at the earliest stage when they are observable by us, point clearly back to a long antecedent development, beginning far away in the remote ages when the Nile dwellers lived on the lower alluvium, where the remains of their life are still buried.

The domestication of cattle, like that of donkeys, reacted powerfully on agriculture, as it was gradually discerned that the hoe might be replaced by the ox-drawn plow. Nothing shows more clearly the evolution of Egyptian civilization as a Nile valley process, than the unnoticed fact that the plow drawn

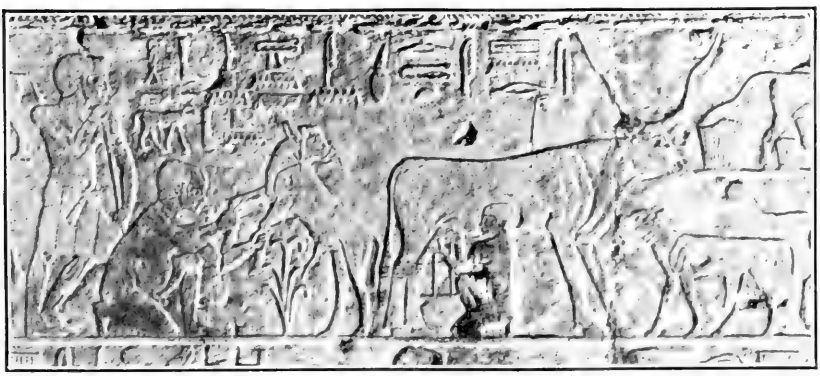


FIG. 32. EGYPTIAN HERDSMEN MILKING. Relief scene in the tomb of Ti at Sakkara, 28th century B.C.

FIG. 33. EGYPTIAN PEASANTS PLOWING. From a tomb relief of the 26th–27th century B.C., now in the Louvre in Paris.

by oxen is simply the old prehistoric wooden hoe equipped with necessary modifications. The primitive form of the Egyptian plow is twice shown in the right-hand column of hieroglyphs in the plowing scene in Fig. 33. Now it can be demonstrated that Egyptian writing has preserved for us pictures of primitive and archaic forms of every day implements, which survived thus in the writing long after they had been displaced by improved forms and hence had ceased to be used in real life. Thus the inscription behind the plowman (Fig. 33) twice displays for us a tiny picture of a form of plow enormously older than the one here shown in actual use. It will be seen that the beam of the plow (in the inscription) is very short, and that the handles are almost too small for use. Indeed this oldest form of the Egyptian plow is little more than the hoe out of which it has developed.

The wooden hoe of the Egyptian peasant (Fig. 34) was made up of two pieces: one, the handle, abnormally short; the other, the blade, disproportionately long. With the exception of the tiny handles shown in the archaic plow just examined in the writing, this hoe is identical with the plow.

An old Egyptian drawing of a plow of about 2000 B.C. (Fig. 34) exhibits clearly the origin of the implement. The handle (of the hoe) has been lengthened to become the beam (of the plow) while the handles for the plowman's use have been sec-

ondarily attached at the point of junction of beam and hoe-blade or plow-share. The builder really constructed a wooden hoe with somewhat elongated handle as plow beam, and then afterward attached the plow handles, which do not engage with the beam or the plowshare, as they would do if they were of one construction with them.

These facts make it certain that the evolution of plow culture from hoe culture took place *in the Nile valley.* Indeed we are here tracing in the gradually developing material basis of life, a process which bears the stamp of the Nile valley, and is unmistakably Nilotic throughout its course.

Here then, so far as we can see, for the first time in the career of man, and at only one point in the fringe of hunting life which encircled the whole Mediterranean, there grew up at its southeast corner (Fig. 2) far back in the fifth millennium before Christ, a community of Stone Age men who had gradually shifted from the hunting life to that of herdsmen and shepherds, plowmen and cultivators of the soil. While it may have required over six thousand acres to support a hunter and his family, a very few acres would maintain the grain-raising, cattle-raising Stone Age family, and the population must have greatly increased in numbers and in density. Such a body of population following the agricultural and cattle-breeding life at the southeast corner of the Mediterranean must inevitably have exerted an influence on surrounding populations. Such a diffusion as that which carried Central American culture traits

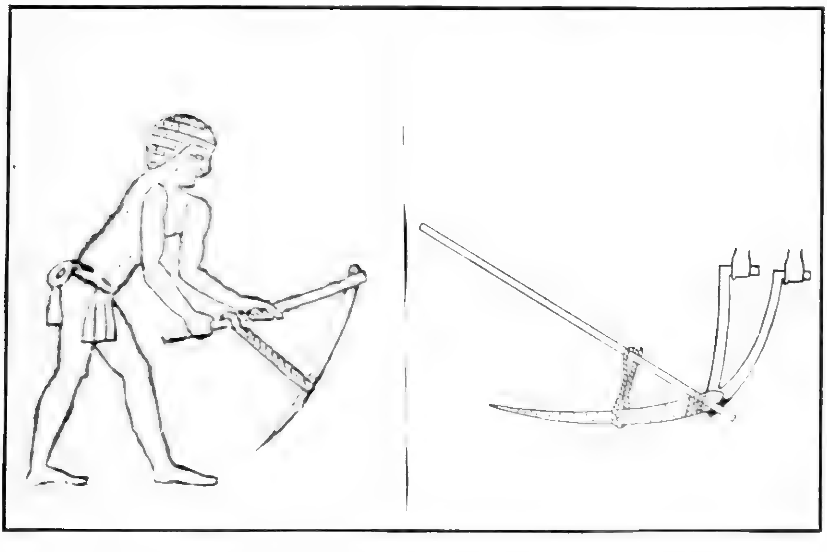


FIG. 34. AN EGYPTIAN WOODEN HOE AND THE WOODEN PLOW WHICH GREW OUT OF IT.

northward and southward until they penetrated far across both North and South America must inevitably have taken place. As to Europe this diffusion was all the easier, because the elevation of the land which made England a part of the neighboring continent, and joined Europe likewise to the mainland of Africa through Italy and Spain—this elevation continued far down into the Neolithic Age, and these land bridges must have been available long after the advances of Egypt just discussed were accomplished (Fig. 2). The same road by which the great African mammals migrated from Africa to Europe was unquestionably still open when the Nile dwellers first began to cultivate fields of grain and breed herds of cattle. It is no accident that the earliest grains of the Swiss Lake Dwellers were barley, emmer and millet, just as in the Nile valley. We have only to look at the dissemination of maize culture in North America from a Central American center to see how easy and inevitable such dispersion is. Moreover, we can actually trace cattle for some distance on the road from Egypt to Europe.

As far back as the middle of the fourth millennium B.C. the Libyans are shown by the Egyptian monuments to have possessed domesticated cattle, sheep and asses (Fig. 24). Such livestock plunder captured by the Egyptians from the Libyans is found in later reliefs also (Fig. 35), which show us large cattle, donkeys, sheep and goats in the possession of a people whose territory stretched far westward along the northern coast of Africa toward Tunis and the region opposite Italy. Thus in remote prehistoric times, Stone Age Europe so long retarded by the ice and cold, began to profit by the progress of the more favored and hence more advanced region at the southeast corner of the Mediterranean. The Neolithic peoples of southern and central Europe were thus able to make the transition from the hunting life, to that of settled communities following agriculture and cattle-breeding. This Neolithic life of Europe, preserved to us especially in the Lake Villages of Switzerland and the *terramare* settlements of the Po valley, was unable to advance by itself to the conquest of metal and the invention of writing, and thus to gain civilization. While interesting, it is of minor importance for the theme of these lectures. Entirely dependent upon the eastern Mediterranean, this Neolithic culture of the West never swung into the current of civilized life until after Greek and Phœnician colonization, and finally Roman conquest gradually civilized it. Its chief importance for our theme is its illustration of the earliest great contribution of the Orient to Europe, as cattle and domesticated grain found their

way across the Mediterranean. The position of this contribution in the long continued westward drift of culture will be found suggested later in Fig. 134.

It now seems to be exceedingly probable, if not a demonstrated fact also, that the south and west European communi-

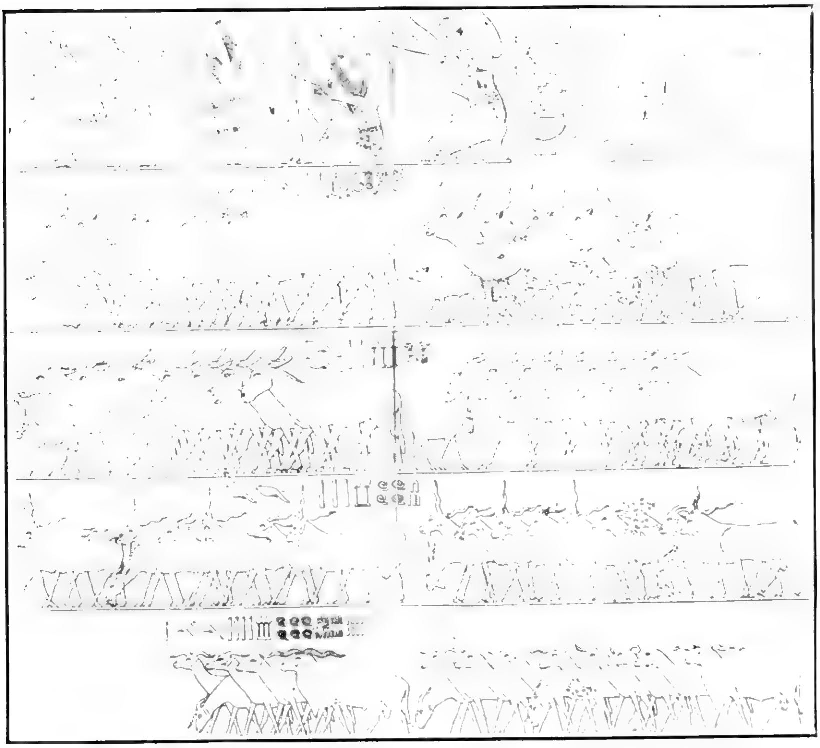


FIG. 35. DOMESTIC ANIMALS OF THE LIBYANS CAPTURED BY THE EGYPTIANS. (28th century B.C.) Compare also Fig. 24. (After Borchardt.)

ties who inaugurated the Neolithic culture of Europe, were of the same race as the prehistoric peoples on the south side of the Mediterranean, or at least as these Egyptians whom we find in the earliest cemeteries. Giving all due consideration to the wide divergence of opinion among the physical anthropologists, it would seem that the studies of Elliot Smith among the largest series of prehistoric Egyptian bodies yet investigated, have demonstrated clearly the identity or close affinity between these prehistoric Egyptians and the south Europeans of the great peninsulas, called by Sergi the Mediterranean race. As Smith has shown in a restoration of a profile from an early predynastic skull (Fig. 36), and as we see also in a late pre-

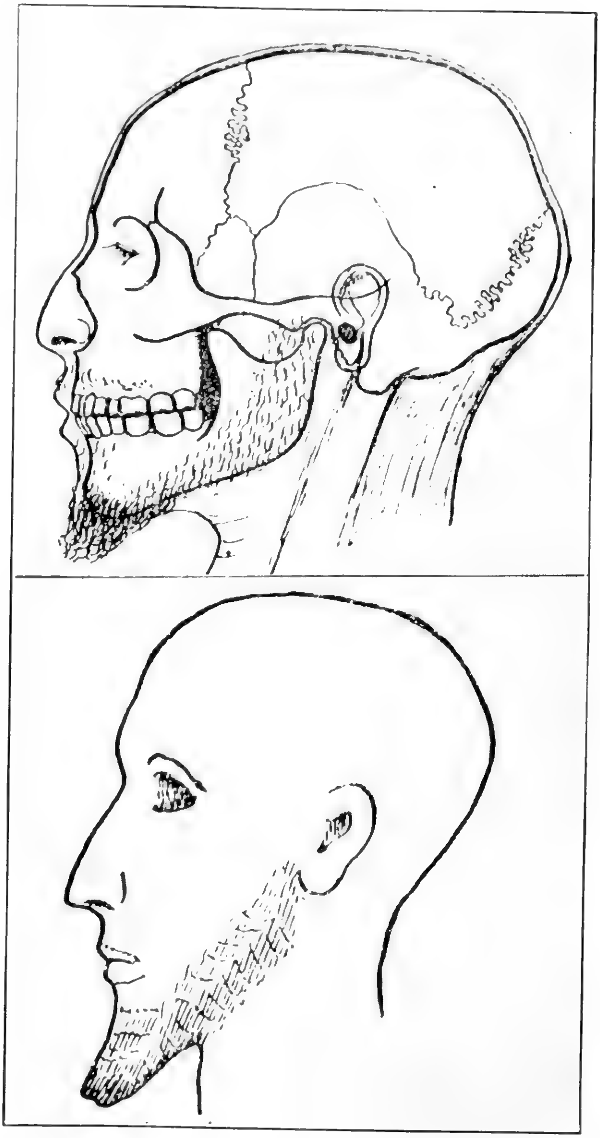
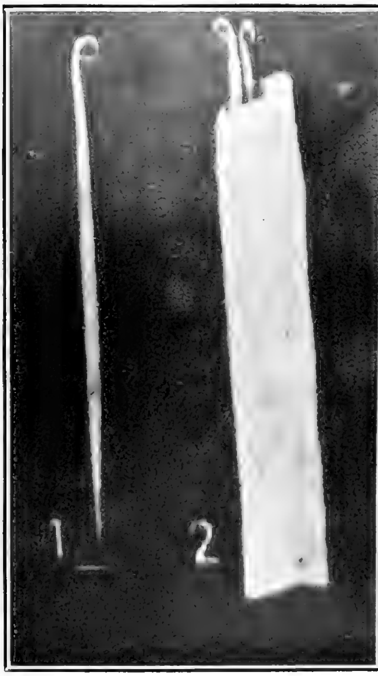


FIG. 36. PROFILE OF A PRE-HISTORIC EGYPTIAN (ABOVE) RESTORED FROM AN EARLY PRE-DYNASTIC SKULL BY DR. ELLIOT SMITH, AND HEAD OF A LATE PRE-DYNASTIC STATUETTE. (The latter after Quibell, "Hierakonpolis.")

dynastic statuette, the prehistoric Egyptians were a narrow-headed, long-faced, dark-haired, and almost certainly dark-eyed race. They were rather low in stature (the men a little under 5 feet 5 inches; the women almost 5 feet), and they were of slender build. They were not negro or negroid, and their kin are to be found in Europe, rather than in Africa.

It must have been after a very long career as a settled agricultural and cattle-raising people, that these dwellers on the Nile alluvium discovered and began to use metal. Unlike the domestication of grain and cattle, the introduction of metal was hardly earlier than the dawn of civilization. We can therefore trace the incoming of metal as we cannot follow the rise of agriculture and cattle-breeding. The graves of our early cemeteries (Fig. 22) disclose to us not merely cultivated grain and domestic cattle, but also metal. For in the very earliest of the predynastic graves we find copper needles with the eye produced by bending the butt around in a hook-eye (Fig. 37). Copper beads and bracelets also show that the earliest use of the metal was chiefly for ornaments. These needles are the earliest implements of metal smelted and wrought by man; for they carry this primitive and limited use of the metal back into the fifth millennium B.C., that is back of 4000 B.C. Man thus began to smelt and use metal about six thousand years ago.



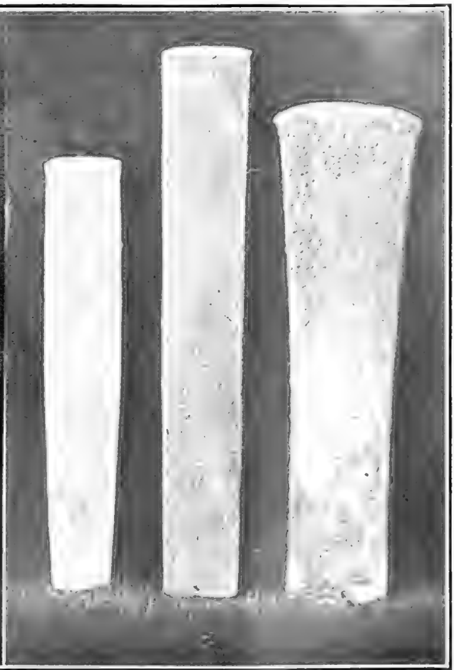


FIG. 37. COPPER NEEDLES WITH HOOK-EYES, THE EARLIEST KNOWN IMPLEMENTS OF METAL. Such needles are found in Egyptian graves dating before 4000 B.C. (After Reisner.)

FIG. 38. THE EARLIEST KNOWN METAL TOOLS: CHISELS OF COPPER FOUND IN PREDYNASTIC EGYPTIAN GRAVES ABOUT 35TH CENTURY B.C. (Photo by Petrie.)

Gradually the Nile-dwellers learned that the metal which they were using for ornaments might be made into tools and weapons, giving them a new power over men and nature. With tools and weapons like these (Fig. 38), which appear in the late pre-dynastic graves by the middle of the fourth millennium B.C., when all the world was elsewhere using only stone implements and weapons, the life of man entered upon a new epoch and at the southeastern corner of the Mediterranean a mechanically gifted people began to respond rapidly to the possession of this new source of power. This response of an ingenious people to the possession of metal culminated in the emergence of a united nation, the first great social and administrative structure erected by man, whose organized capacity was, half a millennium later, to be expressed in monumental form in the pyramids of Gizeh.

The process of political unification which went on among the prehistoric petty kingdoms and chieftaincies distributed along the Nile, is only dimly discernible in the scanty monuments surviving from this remote age. We see these early leaders bearing pointed metal weapons in the hunt, for the Nile-dwellers continued their old hunting habits for thousands of years after the rise of civilization. Monuments from the middle of the fourth millennium show us the Nile chieftains still following the chase (Fig. 39). But even such a document as this hunting scene (Fig. 39) also clearly discloses something of the vast social and governmental progress made by the earliest men, a progress which had carried them away from reliance on the chase, toward the possession of a stable food

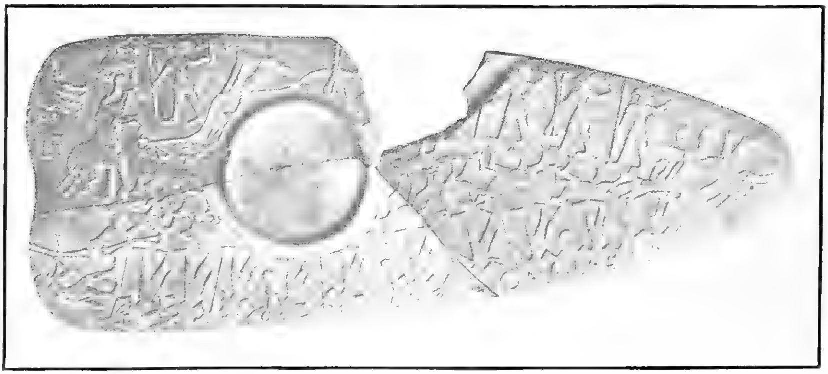


FIG. 39. NILE CHIEFTAINS OF THE MIDDLE OF THE FOURTH MILLENNIUM B.C. ENGAGED IN HUNTING. Depicted in a relief on a slate palette used for grinding face paint. (After Legge in *Proceedings of the Society of Biblical Archæology*, Vol. XXII.)

FIG. 40. A ROYAL DIGGING CEREMONY OF EARLY DYNASTIC AGE DEPICTED IN A RELIEF ON A CEREMONIAL MACE-HEAD. (From Quibell, "Hierakonpolis.")

supply available to large communities abiding in fixed dwelling places. These hunting chieftains carry standards on which are mounted symbols signifying political divisions—the earliest such symbols known. We recognize in them prehistoric forms some of which are well known to us in later hieroglyphic signs. Thus the fifth hunter in the upper line carries a symbol mean-

ing "the East" in the hieroglyphic of half a millennium later. Each hunter also wears attached to his girdle behind, the tail of a wild animal—a symbol retained in historic times only by the Pharaoh.

One of the most powerful influences toward unity and organized development in a rainless climate like that of Egypt, was the necessity of creating an ever more complicated irrigation system. To maintain such a system, to keep each of its long canals free from obstruction, and to control the supply of water, required the cooperation of large groups of communities, created a consciousness of community of interest and a willingness to submit to a central authority in control of the whole. One of the ancient prehistoric rulers shown in Fig. 40 beside a canal wielding an archaic wooden hoe, is evidently engaged in ceremonially digging up the earth, for which his attendant holds a basket. Such a ceremonial act may well have marked the beginning or dedication of some irrigation canal. Thus the possession of grain fields, and the maintenance of herds which must be pastured, bound great groups of communities to a common system for the support of the whole, which could never have grown up among the hunting chieftains of earlier days.

By the middle of the forty-third century B.C., this system had brought forth a calendar of twelve thirty-day months, and five feast days at the end of the year. This is the calendar which has descended to us through the Romans, though it should be observed that the Egyptian rulers were far too practical to make a calendar which would oblige their people to learn a verse of poetry in order to find out how many days there were in a given month.

(To be continued)

THE MEANING FOR HUMANITY OF THE AERIAL CROSSING OF THE OCEAN

By Dr. GEORGE de BOTHEZAT

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THE recent great achievements of the American and British aircrafts show in a striking manner that we are on the eve of the establishment of regular transoceanic aerial voyages. How many centuries, first of audacious dreams, afterwards of daring efforts, were necessary, before this magnificent and powerful realization!

Transoceanic aerial flight is such a powerful factor in humanity's progress and evolution that I fear the language used to-day by human beings is scarcely adequate to describe the magnificent destiny it will produce. This is why I ask indulgence for the audacity of this attempt to analyze the significance of this majestic achievement.

In the aurora of the centuries taken for the blossoming of humanity on our sorrowful planet, the evolution of man started very slowly. Left to himself, with only his physical forces to lead him towards an unknown destiny, of whose greatness, however, he had an unconscious feeling, man would have succumbed under the superiority of innumerable adversaries and adversities, if it had not been for the gleam of consciousness that was smouldering within him. It is the omnipotence of this consciousness that has subdued the universe to man and has made him its uncontested master. It is this consciousness that caused the majestic process of biological evolution to take a new form. The adaptation of the species to outside conditions was transformed into the adaptation of outside conditions to the species, and it is this modification of the biological path that marks the origin of humanity.

The first steps were exceedingly slow and laborious. The first conquests of prehistoric civilization stretch over an immensity of time. But the different halting-places of history are marked by a rate of progress more and more accelerated. It is sufficient to open our eyes simply on our modern world to be amazed by the rapid march of civilization. If, now, through all past time, up to our present days, we contemplate this rapidly

accelerating rate of progress, one primordial factor will appear, which is the soul itself of this accelerated ascent towards a destiny more and more luminous. It is the intensification of the relations between men established by ways of communication.

As soon as the sedentary state of peoples began to succeed the nomad state, the necessity of routes and their enormous utility were instinctively felt; and animal locomotion, whose origin disappears in the night of time, brought even in antiquity the art of route building to a high degree of perfection. The great civilizations of the ancient world were already celebrated for their marvelous roads and maritime routes. Babylonia, Carthage, Greece and the Roman Empire developed majestic routes which excite our admiration; and the traces of some of them still remain. In the civilizations that followed these epochs, in the Middle Ages and the Renaissance, it is easy to note that the march of progress is intimately connected with the development of ways of communication. This fact is generally expressed in speaking of the influence of voyages, of the relations between peoples and the discoveries of new ways and routes. The influence of the technical perfection of the ways of communication is to be seen in a particularly striking manner in the century of steam, marked by such a distinctly powerful progress.

It is impossible to note in a short sketch all the ways in which methods of communication influenced the evolution of humanity. An enormous work could be written on this subject. The essential facts are that almost all human activity on our planet consists in "displacement," and the more easily this displacement is made the more the life of man is extended, and the more powerful it becomes. Our life is built up from motion; to open new routes is to hasten and strengthen its development.

One great factor dominates the whole problem of ways of communication. It is "speed." It is not sufficient to have routes running in all directions and covering great distances; it is all-important for the actual motion to be as rapid as possible. The great influence of speed in the social organization of human activity is not always recognized sufficiently. For example, one can mention the fact that Napoleon in the last years of his power expressed some doubts as to the value of Stephenson's railroads. We must not be astonished if the entire extent of the influence of the speed factor is not realized by all, probably because it is too vast in its majesty and power. But some of us have within ourselves a feeling, more powerful than the conscious reason, which instinctively tells us what speed is. Do you know what speed intoxication is? Happy are those who can

feel it without having to understand it. It is the powerful voice of the innate forces of progress speaking in them. It is the intuition of the future all-inclusive power of humanity, of which, as an echo of destiny, they have the sweet enjoyment. Do you remember the glorious Greek warrior who immolated himself to the speed god, bringing to his fellow-citizens the great news of the Marathon victory, so that their knowledge of social security might be hastened, even by only a few moments? This hero of antiquity, by a striking act, has made immortal his veneration for speed. Great men and great peoples have always paid a worthy tribute to speed. A beautiful example is given by the development of the United States, where the social importance of the speed factor has been understood from the origin of the country, a country which, in the hands of an energetic and intrepid people, has been brought to that powerful and majestic state which we can but admire.

Speed of transportation means acceleration of activity, increase of the people's efficiency, and, as a result, economy of time, with all its enormous consequences. Saving of time brings leisure for meditation and personal improvement, which are the original sources of all progress.

Speed of transportation means also increase of human lifetime, which always was and is one of the most burning desires of man, and hence one of his greatest felicities. To live means to act, to feel and perceive. It is the amount of the perceptions lived that marks the duration of a life-time more than the number of years elapsed. It is not given to us to increase the duration of our lives, but it depends upon us to use our lives better and to fill them with more sensations. I am prepared to assert that the life of a modern man is effectively longer than the life of a man of antiquity, although of the same duration. We have now more to live through, although we live no longer. Our gathering of sensations is much ampler and much more diversified, and they emanate from a much wider horizon. Peter the Great, that powerful reformer of Russia, has expressed this deeply philosophical idea by the significant words: "Waste of time is death-like."

Ask the scientist whether he considers the universe as eternal or doomed to an indubitable end, and you will hear him say that over the entire universe the sinister shadow of the omnipotence of entropy is hovering, and demands an absolute end by a complete thermic uniformization. If, now, not only our personal life, but the course of all humanity is limited, let us at least make the best use of the time left to us. Speed is

our most powerful ally. Let us use it, develop it, and venerate it. It is in infatuation with it that is found the most powerful source of happiness.

Another important rôle is also inherent to the speed factor. One of the great consequences of the establishment of ways of communication is to bring men and peoples to know one another better and consequently to understand each other better and to unite their efforts in the great march of social evolution. The greater the intensification of relations between peoples, the more rapid is the speed of what can be called the uniformization of humanity. In past times, geographical obstacles separated men into different groups called peoples. The conditions under which the lives of different peoples were taking place were unlike, and, although all associations of men, by their nature, progress in the same direction, it is with such dissimilar psychological physiognomies, that, when these different peoples in the process of their evolution were brought together, they could only fight one another to death, each considering the other as his worst enemy. Men did not recognize man in men. But the evolution of man progressing, and distances being conquered by ways of communication, the uniformization of humanity was growing. It is first the uniformization of social customs and material living conditions that is established. Afterwards the uniformization of morality and psychology begins to appear. It is self-evident that social uniformization does not at all bring with it the uniformization of individuals, whose personality is fixed by the qualities and talents given to each man by nature. The great wrong of the Bolsheviki doctrine[1] is that it has completely overlooked the difference between social uniformization and individual uniformization. Regardless of what men will think or do, the whole of humanity will tend towards social uniformization, but individual uniformization is and always will be a tendency contrary to the nature of things and progress. That is why, regardless of the development it may reach, Bolshevism is doomed to failure or complete reformation. I will not dwell here on the question of how social organization has to be conceived in agreement with the principle of social uniformization; this would carry us too far from our main subject. Now this fundamental process of social uniformization is far from being accomplished on our planet. But I would like to believe that the Great War, from

[1] The author of this paper has lived for six months under Bolsheviki rule and is well acquainted with Bolsheviki doctrine and its practical realization.

which we are still bleeding, marks one of its last halting-places. The World's Peace, the universal social union, will only then be able to reign in all its luminous beauty when the process of social uniformization shall have reached a certain stage of development. The most powerful stimulant to universal social uniformization is above all the closeness of international relations. The more rapid are the means of communication, the more will all peoples be, so to speak, neighbors to one another, the more will they jostle one another and be able to know and appreciate each other, and the great universal human family will rise the more rapidly. The century of steam and electricity has already brought the universe to such a state of development that we see on the horizon the dawn of a universal league, somewhat rachitic, but let us hope still a league of nations. It is a wonderful thought indeed, in our epoch of sharp hate and underhanded revenge, to see the great country of America, in a magnanimous glow in advance of the men and the times, claiming with its powerful voice the union of people in the League of Nations. Universal harmony is the highest ideal of every man conscious of his destiny. Let us help those who have not until now reached the social height necessary to step over the marvelous threshold of the future kingdom of mutual agreement and friendship.

The life of man goes on surrounded by three "elements": earth, water and air. Each of these may be used as a way of communication.

On the earth we must trace our routes, and when these are once established we must always follow them. Terrestrial routes have passed through different well-known stages of development and have now reached a high degree of perfection, in the sense of speed as well as in weight of material transported. But whatever improvements may be realized in terrestrial routes, the fact will always remain that the roads have to be built, and when built they remain limited to their original itinerary, and unite only different parts of the same continent.

Water ways have the advantage over land ones of being furnished by nature; and in the immensity of the seas and oceans ships and boats are free to follow all directions. But the hatreds between men, even here, have created insuperable hindrances; some think, for the advantage of the one and the harm of the other, but in reality for the disaster of all humanity. Moreover, water ways unite only different parts of different continents, or, by rivers, give only a limited access within the continents.

The conquest of the air, the marvelous realization of the end of the twentieth century, has finally given us the aerial way of communication, the first to be universal. Air routes have absolute advantage over earth and sea routes, for instance, in the attainment of greater speed, and the possibility of travel at different altitudes. This last factor can never be overestimated, on account of the new features it introduces. At least there has been acquired by it the possibility of looking on our planet from a higher standpoint, and many consequences of great importance will follow from this bird's vision given to man's brains. It has been during long centuries the dream of humanity to fly over seas and lands, to travel through space in rapid flight, following only the will of fancy. But, the first enthusiasm past, when airplanes and airships began to fly, their range appeared to be less than the expectations of the dreamers. Aircraft could fly over earth and seas, but the oceans still remained obstacles to them. And although we felt the possibility of flight over the ocean, we were unable to realize it. The universality of the air routes still remained unrealized. But the scientific and technical workers and investigators by their indefatigable efforts have brought aircraft to such a degree of perfection that finally the immensity of the ocean has been overcome. From this moment on, aircraft has become really the first universal way of communication. I can not refrain from mentioning here some of the glorious names of those men to whom humanity owes the great technical development of aviation.

It was probably the British mathematician Cayley who had the first vision of the airplane (1809). It was the French mathematician Penaud who reached such an understanding of aerodynamical sustentation that he was able to build the first airplane model that actually flew (1872). But it was the German engineer Lillienthal who first reached the wonderful result of making the air really lift him, as he demonstrated in a brilliant series of gliding flights (1891). It was Langley and Chanute who, by remarkable experiments, strengthened the principles established by Lillienthal. And finally, it was the brothers Wright who succeeded in taking the decisive step and realized that marvelous thing, the airplane (1903). In the European countries it is to the powerful personality of Ferber that we owe the development of aviation. In a remarkable book[2] left by this scientist and gallant prophet of aviation we

[2] F. Ferber, "L'Aviation, ses debuts, son developpement," Paris, 1908, published by Berger-Levrault.

read his forecast: "From hill to hill, from town to town, from continent to continent." It is the realization of these beautiful words that we have now reached.

We thus find ourselves now on the eve of the establishment of great universal aerial voyages, transoceanic as well as transcontinental; and with them, by the power of the intensification of the relations between peoples, we will progress towards universal harmony, and approach, in spite of obstacles, a luminous destiny at a rate of progress unknown before.

Let all who still doubt the all-powerful influence of universal air routes think only a little of your daily activity, and you can not help being enthusiastic about all the new and wonderful possibilities that the development of air navigation will give you. Whoever you are, air navigation will load you with its powerful benefits. If you are a business man or merchant, one of those who have appreciated better than others the speed factor, think for a minute that you will have the neighboring continents at a day's distance from you. Your associates from other continents will be able to join you in twenty-four hours. The samples that you may need will be delivered to you on your request in the same length of time. You will be able to travel over enormous distances at tremendous speeds, and scrutinize enormous spaces by your spirit of enterprise. If you are an engineer, scientist or investigator, you will be able to get the necessary book, apparatus or information from any other part of the world in a time less than previously required to get the same from the same province. Think a little, you leaders of human activity, of all the wonderful possibilities that will follow from the new aerial universal ultra-rapid routes, and your keen minds will not need to be convinced of the miraculous activity of future destiny. And all you other less active members of human society, in addition to the comfort, speed, and security of the air routes, you will see flowing around, as from a cornucopia, the products of welfare created by the active members. But all these results just described are small details in comparison with the new human psychology which will progressively result from this era of activity at a rate unknown before, and which without any doubt will reveal to the future the superman of spirit, soul and beauty.

The crossing of the ocean by the airplane makes aircraft the first universal means of transportation, and by this fact alone opens a new era of civilization, with such an increased rate of progress that it is almost impossible for the human mind of to-day to appreciate its whole significance. Acceleration of

human activity will increase the world's welfare; and at the same time the resulting economy of time and individual liberty will lead to the perfecting of the human race in a deep and increasing feeling of happiness, the result of the intensification and multiplicity of sensations, this whole wonderful process of progressive evolution being crowned by the spirit of universal harmony. Aircraft, having become by the crossing of the ocean the universal means of transportation, thus appear as one of the most sublime conquests of civilization, by whose luminous destiny our poor imaginations can only be dazzled.

But this wonderful destiny, which we now foresee, whose rising has begun and the means of reaching which we have already in hand, will require a certain time for its blossoming. Such delay in the realization of one of the most beautiful conquests of humanity is a consequence of what, with much indulgence, is called social inertia. I do not wish to enter into the details and the analysis of this complex phenomenon, and will mention only one of its most painful sides. I apologize for stating the fact so directly. I am guided only by the desire to bring in this way a more intensive feeling of what I intend to say. Why do you, humanity, let yourself be governed by the most ignorant among your fellow-creatures? I will explain myself plainly. At the present time the social power, to a crushing degree, is in the hands of what may be called the "classical humanists." Who are they? Independent of their literary, juristical or other specialty, their mentality once cleared from the sophistical fog with which they are so clever in surrounding themselves; with their official logic, which is nothing else than a brilliant example of reasoning to be used when truth has to be avoided, we see them appearing only as experts in the dismal art of knowing the degree of decay which human nature can reach. It is exactly the contrary of what we need the most, that is, to know what is the degree of perfection that humanity can reach. The ethics of the classical humanist developed under such conditions is not in line with sufficiently powerful and valuable ideals. This is why their political activity provokes so often such social disaster. But to-day we are standing on the eve of a marvelous new era. Among the seekers for truth, among the scientists, engineers, and experts in different technical arts, a new ethics has grown, animated by the most powerful and magnanimous sentiments of justice and universal benevolence, to which they have been brought by the contemplation and study of nature. It is upon the ethics of the men who have an exact knowledge of these con-

crete facts that depends the welfare of humanity. It is by these competent and best men of humanity, masters of the physical world, that the people ought to let themselves be led. The fight between the two tendencies has already begun. It is the fight between the ethics of scholastic ignorance and the ethics of scientific verity. This fight is an old one, but has taken in modern times a new form. It is to Dr. George Sarton, professor of Harvard University, that we owe a brilliant, vigorous and rigorous exposé of this social state of things, which he designates by a name full of destiny, "The New Humanism."[3] Any eloquence of mine would disappear before the words of full conviction of this defender of one of the most beautiful social movements, the understanding of which will without any doubt make us avoid many disasters of the future. Workers in science and technical arts, you have the duty of uniting about the powerful ideals of the "New Humanism," and it will not be long till the light of welfare will pierce the darkness of the classical humanist. The fate of humanity is in progress; this is why the victory of the "New Humanism" can not be stopped. But let us reach it by the peaceful way of conscious evolution, and not by the way of bloody revolution, whose specter stands ready to spread itself over the earth's surface. Modern humanity has a long step to make; it is that of emancipation from the prejudice of the classical humanist. Let us take this step heroically, having the courage to recognize our errors without persisting in our mistakes, without concealing by the sophistries of the classical humanists the actual social wounds, and without crushing by ignorance the benefits of science.

To see how far science is from being sufficiently appreciated to-day, it is enough to compare in the budget of any state the appropriation for science and the appropriations for criminality, for example, this last word being understood in its widest sense. The comparison is illuminating. I will not insist on this painful side of modern social life.

I have considered it necessary to mention here the "New Humanism" for the purpose of showing that the evolution of humanity, although bound up with technical conquests, depends, for the rapidity of its progress, also in a large measure upon social morality. The one brings the other with it.

I allow myself to express the intense desire to see the universe conquered by the "New Humanism," spreading through

[3] George Sarton's "Le Nouvel Humanisme," *Scientia*, March, 1918; see also THE SCIENTIFIC MONTHLY, September, 1918, "The Teaching of the History of Science."

the earth by the powerful transcontinental and transoceanic air routes; and then it will not be long before universal peace, so longed for by every one, becomes a natural phenomenon.

Since the origin of the universe, the complete conquest of the air, now realized by the crossing of the ocean, is the most important factor ever reached in the evolution of humanity.

The history of all mankind is merely the history of its fight against slavery by the forces of nature. Science is our powerful liberator; it teaches us how to use these forces for our own benefit. How many billions of mechanical horsepower are already working for us! To them we owe all the beauty of modern civilization. Workers in technical arts and sciences, you must be firm in your convictions, in the face of social ignorance; your efforts are tracing the path of man's highest destiny.[4]

[4] It is a special pleasure for the author to address his heartiest thanks to Dr. J. S. Ames for the help he gave him in correcting the style of this article.

WAIYAUTITSA OF ZUÑI, NEW MEXICO

By ELSIE CLEWS PARSONS

NEW YORK CITY

ONLY twice through my association with Pueblo Indians has it occurred to me to be a feminist. The first time was at Cochiti when late at night my tired and sleepy Indian hostess grumbled in the soft tones no Pueblo woman ever loses, grumbled because she had to sit up for the young husband who was spending the evening at the club, *i. e.*, taking part in a ceremonial at the estufa. "I'll have to get him something to eat," she said, "no man here would ever cook for himself at home. They say if they did, they would lose their sense of the trail." Rationalization of habit or desire is not confined to the peoples of western civilization.

The second time I remembered I was a feminist was when the editor of a certain journal asked me to write an article on Zuñi women. Are the women of a community still thought of, I queried, even in scientific or pseudo-scientific circles, as a separable class? If so, there is nothing for us but to keep on with the categories of feminist and anti-feminist, tiresome though they become.

Well, the article was written, but it was not published because it contained a reference to the lack of prostitution at Zuñi. Recognition of the subject was considered unsuitable for boy and girl readers; it was deemed better for them to have a partial survey of the facts of life than to see life whole, even at Zuñi. Nor was life at Zuñi to suggest inquiry into life at home.

But writing the article served at least one purpose. It focused attention upon the differentiation of the sexes at Zuñi and resulted in an analysis which contributed to the understanding of a considerable portion of Zuñi habits of mind and of culture. To get the survey which leads to the analysis, let us follow the life of a baby girl we shall call Waiyautitsa, a girl's name, for sex generally appears in Zuñi personal names. Sex appears somewhat in speech too. Waiyautitsa in learning to talk will make use of expressions, particularly exclamations, peculiar to women. Recently Dr. Kroeber, in giving us a list of

the first words used by a Zuñi child, a boy, noted the comparatively large number of kinship terms in his vocabulary. The kinship terms of our imaginary little girl would be somewhat different from a boy's. He calls a younger sister *ikina;* a younger brother, *suwe;* she calls either *hani,* meaning merely the younger. And, as the Zuñi system of kinship terms is what is called classificatory, cousins having the same terms as brother and sister, Waiyautitsa has even fewer words than her brother to express cousinship.

When Waiyautitsa is three or four years old she may be recognized as a girl not merely from her speech, but from her dress, from her cotton slip; at this age little boys wear trousers. But not for another three or four years, perhaps longer, will Waiyautitsa wear over her cotton slip the characteristic Pueblo woman's dress,—the black blanket dress fastened on the left shoulder and under the right arm and hence called in Zuñi *watone,* meaning "across," the broad belt woven of white, green and red cotton, the store-bought kerchief or square of silk (*pitone*) which, fastened in front, hangs across shoulders and back, and the small foot, thick leg moccasins which cover ankle and calf in an envelope of fold upon fold of buckskin. Before Waiyautitsa is eight or even six she may, however, when she goes out, cover her head and body with a black blanket or with the gay colored "shawl" similarly worn. And I have seen very little girls indeed wearing moccasins or the footless black stockings Zuñi women also wear, or "dressing up" in a *pitone,* that purely ornamental article of dress without which no Zuñi woman would venture outdoors. Without her *pitone* she would feel naked, she says, and any man would be at liberty to speak disrespectfully to her. When Waiyautitsa is about five, her hair, before this worn, like the boys, in a short cut, is let grow into a little tail on the nape of her neck. In course of time her pigtail will be turned up and tied with a "hair belt" of white, green and red cloth. From ear to ear her front hair will be banged to the end of her nose, the bang drawn sidewise above the forehead except at such times in ceremonials when it is let fall forward to conceal the upper part of the face.

This hair arrangement serves in ceremonials as a kind of mask. A mask proper, that *quasi* fetich which has so important a place in Pueblo ceremonialism, Waiyautitsa will in all probability never wear. Unlike her brother, Waiyautitsa will not be initiated in childhod into the *kotikyane* or god society, and consequently she will not join one of the six *kiwitsiwe* or sacred club-houses or estufas which supply personators for the

masked "dancers." Not that female personages do not figure in these ceremonials, but as was the rule on the Elizabethan stage women are impersonated by men.

To this exclusion of girls from the *kotikyane* and from participating in the masked "dances" there are, we should note, a few exceptions. To-day three women belong to the *kotikyane.* They were taken into it not in childhood, but in later life and, it is said, for one of the same reasons women as well as men are taken into the other fraternities or societies of Zuñi. Cured by ceremonial whipping of the bad effects of nightmare or of some other ailment, they were "given" to the *kiwitsine* credited through one of its members with the cure. Of the three women members only one is said to dance, and she is accounted mannish, *katsotse,* girl-man, a tomboy.

Waiyautitsa will not be initiated, it is not very likely, into the *kotikyane,* but she is quite likely to be initiated into another society,—into the Great Fire or Little Fire or Bed Bug or Ant or Wood society, into any one of the thirteen Zuñi societies except three, the bow priesthood or society of warriors, of warriors who have taken a scalp, or the Hunter Society or the Cactus Society, a society that cures arrow or gun-shot wounds. As women do not hunt or go to war, from membership in these groups they are excluded or, better say, precluded. As we shall see later, affiliation by sex is in ceremonial affairs along the lines of customary occupation.

If Waiyautitsa falls sick and is cured by a medicine-man of the medicine order of a society she must be "given" either to the family of the medicine man or to his society. Initiated she may not be, however, for a long time afterwards, perhaps for years. Initiations take place in the winter when school is in session, the school either of the Indian Bureau or of the Dutch Reformed Church, and for that reason, it is said, initiations may be postponed until past school age. Despite the schools, I may say, I have met but two Zuñi women who speak English with any fluency. One woman is a member of the Snake-Medicine Society, into which she was initiated after convalescence from measles, a decimating disease at Zuñi, to be accounted for only through witchcraft. The other woman was accounted the solitary convert of the Dutch Reform Church Mission in Zuñi until six or seven years ago she joined the Wood society because as a child she had been cured by them of smallpox.

After initiation, the women, like the men of a society, offer feather-sticks each moon, observing continence for four days

thereafter, and they join in the four-day retreat in the ceremonial house of the society preliminary to an initiation. Unlike the men, however, the women do not spend the entire night, only the evening, in the society house, and, while there, they are listeners rather than narrators of the inexhaustible folk tales that are wont to be told at society gatherings. Men are the custodians of the lore, secular as well as esoteric, of the tribe, just as men and not women are the musicians. The men are devoted singers, singing as they dance or singing as a choir for dancers, and singing as they go to or from work in the fields or as they drive their horses to water in the river or to the corrals on the edges of the town. Even grinding songs are sung on ceremonial occasions by men.

In the public appearances of the society, the women members figure but little. Societies supply choirs and drummers and ceremonial road openers or leaders to the masked dancers and, during the great *koko awia* (god coming) or *shalako* ceremonial, to various groups of sacred personages. I have seen several "dances" in Zuñi and one celebration of *koko awia,* and I have seen but one woman officiate in public. As a daughter of the house which was entertaining the *koyemshi* or sacred clowns she was in attendance upon that group in the *koko awia* or Advent, so to speak, of 1915.

If Waiyautitsa belongs to a society, she will offer or plant the befeathered prayer-sticks, which are so conspicuous a feature of Pueblo religion, but, being a woman, Waiyautitsa will not cut or dress the sticks. She will only grind the pigments and, perhaps, paint the sticks. Nor as a woman would she offer the sticks on certain other ceremonial occasions when the men offer them. Once a year, however, at the winter solstice ceremonial on which so much of Zuñi ritualism pivots, Waiyautitsa will be expected, even in infancy, to plant, planting for the "old ones," *i. e.,* the ancestors and for the Moon, but not, like the men, for the Sun or, unless a member of the *kotikyane,* for the ancestral gods, the *koko.*

At the conclusion of the winter solstice ceremonial, when certain sacred figures called *kwelele* go from house to house, the women carry embers around the walls of the house and throw them out on the *kwelele.* It is a rite of *shuwaha,* cleansing, exorcism. There are a number of other little rites peculiar to the women in Zuñi ceremonialism. Through them, and through a number of rites they share with the men, through provisions for supplying food in the *kiwitsine* to the sacred personators or for entertaining them at home or making them

presents, women have an integral part in Zuñi ceremonialism. In what we may call the ceremonial management, however, they appear to have little or no part.

Even when women are initiated into the *kotikyane,* or are associated with the *ashiwanni* or rain priests, their functions seem to be primarily of an economic or housekeeping order. The women members of the rain priesthoods have to offer food every day to the fetiches of these sacerdotal groups—to stones carved and uncarved and to cotton wrapped lengths of cane filled with "the seeds the people live by." For the seed fetiches to be in any way disturbed in the houses to which they are attached involves great danger to the people and on a woman in the house, the woman member of the priesthood, falls the responsibility of guardianship or shelter. But even these positions of trust are no longer held by women—there are, according to Dr. Kroeber, only six women *ashiwanni* among the fifteen priesthoods. The woman's position among the paramount priesthood, the rain priesthood of the North, has been vacant now for many years—no suitable woman being willing, they say, to run the risks or be under the taboos of office. Aside from this position of woman *shiwanni,* women count for little or nothing in the theocracy of Zuñi. They were and are associated with the men priests to do the work pertinent to women. In the case of the Zuñi pantheon or its masked impersonations, the association is needed to satisfy or carry out, so to speak, Zuñi standards or concepts of conjugality. The couple rather than the individual is the Zuñi unit. Sometimes, in ceremony or in myth, the couple may consist of two males.

There is one masked couple I have noted in particular at Zuñi, the *atoshle.* Two or three times during the winter our little Waiyautitsa together with other girls and very little boys may expect to be frightened by the *atoshle,* the disciplinary masks who serve as bugaboos to children as well as a kind of sergeant-at-arms, the male *atoshle* at least, for adults. If the children meet the old man and his old woman in the street, they run away helter skelter. If the dreadful couple visits a child indoors, sent for perhaps by a parent, the child is indeed badly frightened. I suppose that Waiyautitsa is six or seven years old when one day, as an incident of some dance, the *atoshle* "come out" and come to her house. The old woman *atoshle* carries a deep basket on her back in which to carry off naughty children and in her hand a crook to catch them by the ankle. With the crook she pulls Waiyautitsa over to the grinding stones in the corner of the room, telling her that now she is

getting old enough to help her mother about the house, to look after the baby and, before so very long, to grind. She must mind her mother and be a good girl. I once saw a little girl so terrified by such admonition—this time by the old man *atoshle,* the old woman not being along—that she began to whimper, hiding her head in her mother's lap until the *atoshle* was sprinkled with the sacred meal and left the house to perform elsewhere his rôle of parents' assistant.

Whether from fear, from supernatural fear or fear of being talked about as any Zuñi woman who rests or idles is talked about, or whether from example, more from the latter no doubt than from the former, Waiyautitsa is certainly a "good girl," a gentle little creature, and very docile. Through imitating her industrious mother or aunt or her even more industrious grandmother or great-aunt, she learns to do all the household tasks of women. She learns to grind the corn on the stone *metate*—that back-hardening labor of the Pueblo woman—and to prepare and cook the meal in a number of ways in an outside oven or on the American stove or on the flat slab on which *hewe* or wafer bread is spread. For the ever cheery family meal she sets out the coffee-pot, the *hewe* or *tortilla,* and the bowls of chile and of mutton stew on the earthen floor she is forever sweeping up with her little home-made brush or with an American broom. (A Zuñi house is kept very clean and amazingly neat and orderly.)

And Waiyautitsa becomes very thrifty—not only naturally but supernaturally. She will not sell corn out of the house without keeping back a few grains in order that the corn may return—in Zuñi thought the whole follows a part. And she will keep a lump of salt in the corn store room and another in the bread bowl—when salt is dug out, the hole soon refills, and this virtue of replacing itself the salt is expected to impart to the corn. There are other respects, too, in which Waiyautitsa will learn how to facilitate the economy. She will sprinkle the melon seeds for planting with sweetened water—melons should be sweet. Seed wheat she will sprinkle with a white clay to make the crop white, and with a plant called *ko'wa* so that wheat dough will pull well. Seed corn will be sprinkled with water that the crop may be well rained on.

From some kinswoman who is a specially good potter Waiyautitsa may have learned to coil and paint and fire the bowls as well as the cook pots and water jars the household needs. She fetches in wood from the wood-pile and now and again she may be seen chopping the pine or cedar logs the men

of the household have brought in on donkey or in wagon. She fetches water from one of the modern wells of the town, carrying it in a jar on her head and walking in the slow and springless gait always characteristic of Pueblo women. That gait, let me say, so ponderous and so different from the gait of the men, is one of the puzzling things about Pueblo women. Is it perhaps the result of their incessant industry, a kind of unconscious self-protective device against "speeding up"?

Waiyautitsa will learn to work outdoors as well as in. She will help her mother in keeping one of the small gardens near the town—the men cultivate the outlying fields of corn and wheat (and the men and boys herd the sheep which make the Zuñi prosperous), and Waiyautitsa will help her household thresh their wheat crop, in the morning preparing dinner for the workers, for relatives from other households as well as from her own, in the afternoon joining the threshers as the men drive horses or mules around the circular threshing floor and the women and girls pitch-fork the wheat and brush away the chaff and winnow the grain in baskets. Waiyautitsa will also learn to make adobe blocks and to plaster with her bare hand or with a rabbit-skin glove the adobe walls of her mother's house, inside and out. Pueblo men are the carpenters of a house, but the women are always the plasterers, and Waiyautitsa will have to be a very old woman indeed to think she is too old to plaster. On my last visit to Zuñi I saw a woman seventy or not much under spending part of an afternoon on her knees plastering the chinks of a door newly cut between two rooms.

The house she plasters belongs or will in time belong to Waiyautitsa. Zuñi women own their houses and their gardens or, perhaps it is better to say, gardens and houses belong to the family through the women. At marriage a girl does not leave home; her husband joins her household. He stays in it, too, only as long as he is welcome. If he is lazy, if he fails to bring in wood, if he fails to contribute the produce of his fields, or if some one else for some other reason is preferred, his wife expects him to leave her household. He does not wait to be told twice. "The Zuñi separate whenever they quarrel or get tired of each other," a critical Acoma moralist once said to me. The monogamy of Zuñi is, to be sure, rather brittle. In separation the children stay with the mother.

Children belong to their mother's clan. They have affiliations, however, as we shall see, with the clan of their father. If the mother of Waiyautitsa is a Badger, let us say, and her

father a Turkey, Waiyautitsa will be a Badger and "the child of the Turkey." She can not marry a Turkey clansman nor, of course, a Badger. Did she show any partiality for a clansman, an almost incredible thing, she would be told she was just like a dog or a burro.

These exogamous restrictions aside and the like restrictions that may arise in special ways between the household of Waiyautitsa and other households, Waiyautitsa would be given, I am told, freedom of choice in marrying. Even if her household did not like her man, and her parents had told her not "to talk to" him, Zuñi for courting, she and he could go to live with some kinswoman. No one, related or unrelated, would refuse to take them in. In Zuñi nobody may be turned from the door. Nor would a girl whose child was the offspring of a chance encounter be turned out by her people or slighted. The illegitimate child is not discriminated against at Zuñi.

Casual relationships occur at Zuñi, but they are not commercialized, there is no prostitution. Nor is there any life-long celibacy. As for courtship, how there can be any, at least before intimacy either in the more transient or more permanent forms of mating, is a puzzle—the separation outside of the household of boys and girls of various ages is so thorough. "But what if a little girl wanted to play with boys?" I once asked. "They would laugh at her and say she was too crazy about boys." "Crazy" at Zuñi, as quite generally among Indians, means passionate. (Girls at Zuñi are warned away from ceremonial trespass by the threat of becoming "crazy.")

The young men and the girls do, to be sure, have non-ceremonial dances together, and in preparing for them there may be opportunities for personal acquaintance. The dance itself seems too formal for such opportunities. I saw one of these dances not long ago. It was a Comanche dance. There were a choir of about a dozen youths including the drummer, four girl dancers heavily beringed and benecklaced, the pattern of whose dance, two by two or in line, was very regular, and a youth who executed in front of them or around them an animated and very beautiful *pas seul*. After dancing outside in the plaza, they all went into "the saints house" to dance for her "because they like her"—a survival no doubt of the custom of dancing in the Catholic church observed by the Indians in Mexico and not long since quite generally in New Mexico. During this same visit to Zuñi, I may say, I also saw one late afternoon, a time for fetching water, a young man take a girl rather brusquely by the arm and try to speak to her. She

averted her head and passed on, another girl only a few steps ahead of her and another not far behind. It was the briefest of encounters and far from private, but it left me no longer quite as sceptical as I had been on being told that at this twilight hour, at least, the girls and the young men do meet. And after "two or four" meetings at the well a girl may agree to marry or, in Zuñi phrase, to have a man.

Well, Waiyautitsa has in one way or another, we shall have to suppose, met her young man and agreed that he is to join her household. At first, for a few days, he will stay in the common room, in the room where all sleep (sleeping and dressing, let me say, with the utmost modesty), he will stay only at night, leaving before dawn, "staying still" his shyness is called. Then he will begin to eat his meals with the household. There is, you see, no wedding ceremonial and a man slips as easily as he can into the life of his wife's household. The Ashiwi, as the people call themselves, take no pleasure in disconcerting one another—ceremonially, at least—nor does the priesthood aim to direct domestic events.

Waiyautitsa will pay a formal visit on her bridegroom's people, taking his mother a basket of corn meal. To Waiyautitsa herself her young man will have given a present of cloth for a dress or a buckskin for the moccasins he will make for her. Hides are a product of the chase, of cattle raising (cowhide is used to sole moccasins), or of trade, men's occupations, and so moccasins of both women and men are made by men. Women make their own dresses, although, formerly, before weaving went out of fashion at Zuñi, it is likely that men were the weavers, just as they are to-day among the Hopi from whom the men of Zuñi get cloth for their ceremonial kilts and blankets and for the dresses of the women. Even to-day at Zuñi men may make up their own garments from store bought goods and it is not unusual to see a man sitting to a sewing-machine.

A man may use cloth or thread for other than economic reasons. In case a girl jilts him he will catch her out some night and take a bit from her belt to fasten to a tree on a windy mesa top. As the wind wears away the thread, the woman will sicken and perhaps in two or three years die.[1] A woman who is deserted may take soil from the man's footprints and put it where she sleeps. At night he will think of her and come back—"even if the other woman is better looking." Apprehensive of

[1] Analogous reasoning leads to the practise of burning scraps in dress-making that they may not fall into the hands of a witch.

desertion a woman may put a lock of hair from the man in her house wall or, the better to attach him to her, she may wear it over her heart. Women and men alike may buy love charms from the *newekive*, a curing society potent in magic, black or white. There is a song, too, which men and women may sing "in their heart" to charm the opposite sex. And there is a song which a girl may sing to the corn as she rubs the yellow meal on her face before going out. "Help me," is the substance of it, "I am going to the plaza. Make me look pretty." Rarely do our girls pray, I suppose, when they powder their noses.

Courtship past for the time being, courtship by magic or otherwise, Waiyautitsa is now, let us say, an expectant mother. Her household duties continue to be about the same, but certain precautions, if she inclines to be very circumspect, she does take. She will not test the heat of her oven by sprinkling it in the usual way with bran, for if she does, her child, she has heard, may be born with a skin eruption. Nor will she look at a corpse or help dress a dead animal lest her child be born dead or disfigured. She has heard that even as a little girl if she ate the whitish leaf of the corn husk her child would be an albino. If her husband eat this during the pregnancy the result would be the same. On her husband fall a number of other pregnancy taboos, perhaps as many as fall on her, if not more. If he hunts and maims an animal, the child will be similarly maimed —deformed or perhaps blind. If he joins in a masked dance, the child may have some mask-suggested misshape or some eruption like the paint on the mask. If he sings a great deal, the child will be a cry baby. The habit of thinking in terms of sympathetic magic or of reasoning by analogy which is even more conspicuous at Zuñi than, let us say, at New York, is particularly evident in pregnancy or birth practises or taboos.

Perhaps Waiyautitsa has wished to determine the sex of the child. In that case she may have made a pilgrimage with a rain priest to Towa Yalene, the high mesa three miles to the east of the town, to plant a feather-stick which has to be cut and painted in one way for a boy, in another way for a girl. (Throughout the Southwest blue or turquoise is associated with maleness and yellow with femaleness.) Wanting a girl, and girls are wanted in Zuñi quite as much as boys, if not more, Waiyautitsa need not make the trip to the mesa, instead her husband may bring her to wear in her belt scrapings from a stone in a phallic shrine near the mesa. When labor sets in and the pains are slight, indicating, women think, a girl, Waiyautitsa

may be told by her mother, "Don't sleep, or you will have a boy." A nap during labor effects a change of sex. When the child is about to be born, Waiyautitsa is careful, too, if she wants a girl, to see that the custom of sending the men out of the house at this time is strictly observed.

After the birth, Waiyautitsa will lie in for several days, four, eight, ten or twelve, according to the custom of her family. Whatever the custom, if she does not observe it, she runs the risk of "drying up" and dying. She lies on a bed of sand heated by hot stones, and upon her abdomen is placed a hot stone. Thus is she "cooked," people say, and creatures whose mothers are not thus treated are called uncooked, raw—they are the animals, the gods, Whites. To be "cooked" seems to be tantamount in Zuñi to being human.

It is the duty of Waiyautitsa's mother-in-law, the child's paternal grandmother, to look after mother and child during the confinement, and at its close to carry the child outdoors at dawn and present him or her to the Sun. Had Waiyautitsa lost children, she might have invited a propitious friend, some woman who had had many children and lost none, to attend the birth and be the first to pick up the child and blow into his mouth. In these circumstances the woman's husband would become the initiator of the child, if a boy, when the child was to be taken into the *kotikyane*. Generally the child's father choses some man from the house of his own *kuku* or paternal aunt to be the initiator or godfather, so to speak, of the child.

The infant will receive many attentions, too, from his mother and her household. He is placed on a cradle board in which, near the position of his heart, a bit of turquoise is inlaid to preclude the cradle bringing any harm to its tenant. Left alone, a baby runs great risk—some family ghost may come and hold him, causing him to die within four days. And so a quasi fetichistic ear of corn, a double ear thought of as mother and child, is left alongside the baby as a protector. That the baby may teeth promptly, his gums may be rubbed by one who has been bitten by a snake—"snakes want to bite." To make the child's hair grow long and thick, his grandfather or uncle may puff the smoke of native tobacco on his head. That the child may not be afraid in the dark, water-soaked embers are rubbed over his heart the first time he is taken out at night—judging from what I have seen of Zuñi children and adults a quite ineffectual method. That the child may keep well and walk early, hairs from a deer are burned and the child held over the smoke —deer are never sick and rapid is their gait. Their hearing,

too, is acute, so discharge from a deer's ear will be put into the baby's ear. That the child may talk well and with tongues, the tongue of a snared mocking-bird may be cut out and held to the baby to lick. The bird will then be released in order that, as it regains its tongue and "talks," the child will talk. A youth who speaks in addition to his native tongue Keresan, English and Spanish has been pointed out to me as one who had licked mocking-bird tongue.

Waiyautitsa will give birth to three or four children, let us say, probably not more, and then, as she approaches middle age, let us suppose she falls sick, and after being doctored unsuccessfully first by her old father who happens to be a well-known medicine-man of the Great Fire society, and then by a medicine-man from the *newekwa* society whose practice is just the opposite, Waiyautitsa dies. Within a few hours elderly kinswomen of her father's will come in and wash her hair and body, and at dawn sprinkle her face first with water and then with meal. The deceased will be well dressed, and in a blanket donated by her father's people she will be carried to the cemetery lying in front of the old church, a ruin from the days of the Catholic establishment in Zuñi. There to the north of the central wooden cross, *i. e.*, on the north side of the cemetery, Waiyautitsa will be buried. Women are always buried on the north side and men on the south.

Waiyautitsa will be carried out and buried by her father's kinsmen or clansmen. No woman will go to the burial, nor will the widower. The widower, as soon as the corpse is taken outdoors, will be fetched by his women relatives to live at their house. There they straightway wash his hair—a performance inseparable in Zuñi as at other pueblos from every time of crisis or ceremony. The hair of all the other members of Waiyautitsa's household will be washed at the end of four days by women relatives of her father. During this time, since the spirit of Waiyautitsa is thought to linger about the home, the house door will be left open for her at night. The bowl used in washing her hair and the implements used in digging her grave will also be left outdoors. Her smaller and peculiarly personal possessions have been buried with her and bulky things like bedding have been burned or taken to a special place down the river to be buried. The river flows to the lake sixty miles or so west of Zuñi where Waiyautitsa's spirit is also supposed to take its journey. There under the lake it abides except when with other spirits it returns in the clouds to Zuñi to pour down the beneficent rain. People will say to a child, when they

see a heavy cloud, "There goes your grandmother," or they will quite seriously say to one another, "Our grandfathers are coming."

Waiyautitsa's children may go on living at home with their grandmother, Waiyautitsa's mother, or it may be one of them is adopted by a maternal aunt or great-aunt or cousin. Zuñi children, cherished possessions as they are, are always being adopted—even in the lifetime of their mother. Adopted, a child—or an adult—will fit thoroughly into the ways of his adoptive household. It is the household as well as the clan which differentiates the Zuñi family group from our individualistic type of family. The household changes quite readily, but whatever its composition, it is an exceedingly integrated and responsible group.

However the children are distributed, it will be the older woman or women in the household who will control them. This household system is one that gives position and considerable authority to the elder women—until the women are too old, people say, to be of any use. (In spite of this irony, I have heard of but one old woman who was neglected by her household.) An older woman who is the female head of the household is greatly respected by her daughters and sons-in-law and grandchildren as well as by the sons or brothers who continually visit the household and often, as temporary celibates, return to live in it.

The older woman is highly esteemed, but she is by no means the head of the household—unless she is widowed. Wherever the household contributes to the ceremonial public life, her husband is paramount. In the non-ceremonial, economic life, too, he has equal, if not greater, authority. And in the general economy he more or less expects his wife to serve him and wait on him. This conjugal subordination is not apparent to any extent among the younger people; the younger husband and wife are too much drawn into the cooperate household life. But as time passes and they in turn become the heads of the household, the man appears to be more given to staying at home, and more and more he takes control.

From this brief survey of the life of a woman at Zuñi in so far as it can be distinguished from the general life, we get the impression that the differentiation of the sexes follows lines of least resistance which start from a fairly fundamental division of labor. From being hunters and trappers men become herders of the domestic animals, drivers or riders. Trade journeys and trips for wood or for the collecting of other natural resources

are associated with men, and work on the things acquired is men's work—men, for example, are wood cutters, and bead makers, whether the objects are for secular or sacerdotal use. Analogously all work upon skins or feathers is work for men whether it leads to the manufacture of clothing or to communication with the supernaturals. Again, as farmers, men are associated with that system of supernatural instrumentalism for fertility and weather control which constitutes in large part Zuñi religion. In other words, the bulk of the ceremonial life, a system for the most part of rain rituals, is in the hands of the men. So is government. The secular officers are merely representatives of the priests. Zuñi government is a theocracy in which women have no part. The house and housekeeping are associated with women. Clay is the flesh of a female supernatural and clay processes, brick making or laying or plastering, and pottery making are women's work. There are indications in sacerdotal circles that painting is or was thought of as a feminine activity. Corn, like clay, is the flesh of female supernaturals, and the corn is associated with women. Even men corn growers are in duty bound to bring their product to their wife or mother. Women or women impersonations figure in corn rituals. It is tempting to speculate that formerly, centuries since, women themselves were the corn growers. To-day, at any rate, the preparation of corn as of other food is women's work. Wherever food and its distribution figure in ceremonials, and there is a constant offering of food to the supernaturals, women are apt to figure. Fetiches are attached to houses and in so far as providing for these fetiches is household work it is women's work and leads to the holding of sacerdotal office by women. The household rather than ties of blood is the basis of family life. The children of the household are more closely attached to the women than to the men. One expression of this attachment is seen in reckoning clan membership through the mother.

Household work at Zuñi as elsewhere is continuous. The women are always on the move. The work of the men, on the other hand, is intermittent. Hunting, herding and farming are more or less seasonal activities and are more or less readily fitted into ceremonial pursuits, or rather, in their less urgent periods, take on ceremonial aspects. In the ceremonial life the arts find expression, and the men and not the women are by and large the artists of the tribe.

Attached to the ceremonial life are the games of chance and

the races that are played or run at certain seasons. Here again the intermittent habit of work of the men together with their comparative mobility qualify them as gamesters and runners to the exclusion of the women. It is even more unusual to see a Pueblo woman run than to see a white American woman, and like white women, Pueblo Indian women seem quite content to pay no attention to games or merely to look on. They engage in no games.[2]

Household work is confining. Hunting, herding, trading lead to a comparatively mobile habit, a habit of mind or spirit which in the Southwest, at least, is adapted to ceremonial pursuit; for Pueblo Indian ceremonialism thrives on foreign accretions, whether of myth or song or dance or design of mask or costume, or, within certain limits of assimilation, of psychological patterns of purpose or gratification.

To the point of view that the differentiation of the sexes at Zuñi proceeds on the whole from the division of labor the native custom of allowing a boy or man to become, as far as ways of living go, a girl or woman, gives color. Towards adolescence, and sometimes in later life, it is permissible for a boy culturally to change sex. He puts on women's dress, speaks like a woman, and behaves like a woman. This alteration is due to the fact that one takes readily to women's work, one prefers it to men's work. Of one or another of the three men-women now at Zuñi or of the men-women in other pueblos I have always been told that the person in question made the change because he wanted to work like a woman or because his household was short of women and needed a woman worker. This native theory of the institution of the man-women is a curious commentary, is it not, on that thorough-going belief in the intrinsic difference between the sexes which is so tightly held to in our own culture?

[2] Formerly women are said to have played with men a ceremonial or quasi-ceremonial game, a pole and hoop game, and to-day the very little girls, besides playing house, play other games. In one of them the girls trace a spiral on the ground and at the center place a bowl of water to represent a spring. They follow the spiral to get water for their little turkeys which, they sing, are dying of thirst. A "bear" rushes out from the spring and gives chase.

THE CONTROVERSY ON THE ORIGIN OF OUR NUMERALS

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RECENTLY certain articles have been written which cast doubt upon the commonly accepted view that our numeral system originated in India and two writers definitely assign a European origin.[1] As the conclusions of these articles have been spread broadcast in popular weekly journals, it seems appropriate that a fuller account giving a digest of the facts and arguments bearing on the question be placed before the scientific public.

Our so-called "Arabic" notation owes its excellence to the application of the principle of local value and the use of a symbol for zero. It is now conclusively established that the principle of local value was used by the Babylonians much earlier than by the Hindus[2] and that the Maya of Central America used the principle and symbols for zero in a well-developed numeral system of their own.[3] The notation of Babylonia used the scale of 60, that of the Maya, the scale 20 (except in one step). It follows, therefore, that the present controversy on the origin of our numerals does not involve the question of the first use of local value and symbols for zero; it concerns itself only with *the time and place of the first application of local value to the decimal scale and with the origin of the forms or shapes of our ten numerals.*

[1] G. R. Kaye, "Notes on Indian Mathematics," *Journal and Proceedings of the Asiatic Society of Bengal*, N. S., Vol. 3, 1907, pp. 475–508; "The Use of the Abacus in Ancient India," *loc. cit.*, Vol. 4, 1908, pp. 293–297; "References to Indian Mathematics in certain Mediæval Works," *loc. cit.*, Vol. 7, 1911, pp. 801–813; "A Brief Bibliography of Hindu Mathematics," *loc. cit.*, Vol. 7, 1911, pp. 679–686; *Scientia*, Vol. 24, 1918, p. 54; "Influence Grecque dans le Développement des Mathématiques Hindoues," *Scientia*, Vol. 25, 1919, pp. 1–14.

Carra de Vaux, "Sur l'origine des chiffres," *Scientia*, Vol. 21, 1917, pp. 273–282.

Nicol. Bubnov, "Arithmetische Selbstständigkeit der europäischen Kultur," Berlin, 1914. (Translated from the Russian edition, Kiev, 1908.) "Origin and History of our Numerals," Kiev, 1908 (Russian).

[2] M. Cantor, "Vorlesungen über Geschichte der Mathematik," 1. Bd., 3. Auflage, Leipzig, 1907, pp. 24–43. Cantor gives bibliographical references.

[3] C. P. Bowditch, "Maya Numeration, Calendar and Astronomy," Cambridge (Mass.), 1910; S. G. Morley, "Introduction to the Study of the Maya Hieroglyphs," Washington, 1915.

That our numerals were of Hindu origin has been the belief held by individual European writers since the Renaissance. Following the publication of M. F. Woepcke's articles, particularly his "Mémoire sur la propagation des chiffres Indiens,"[4] it came to be generally accepted by mathematical historians. Only recently have dissenting voices been heard. Three writers, G. R. Kaye, Carra de Vaux, and Nicolaus Bubnov, represent the new claims. The last two writers place the weight of their authority on the side of an European origin.

The arguments upon which the Hindu origin of our numerals has been based are essentially three in number: (1) The use of the numerals in ancient Indian inscriptions, (2) the early Indian use of the abacus, (3) the testimony of Arabic writers.

G. R. Kaye, who, on this question, is far more careful, conservative and thorough than the other two investigators, has studied the Hindu numerals in connection with the general history of mathematics in India. He has made important contributions to this subject.

As regards the first argument, relating to ancient Hindu inscriptions, Kaye refers to seventeen inscriptions antedating the tenth century A.D. which have been supposed to contain our decimal place-value notation and to indicate the Indian origin of our numerals. The inscriptions are copper-plate grants. Many such grants are now known to be forgeries, fabricated about the end of the eleventh century, when there was "great opportunity to regain confiscated endowments and to acquire fresh ones." Students of epigraphy have eliminated from these seventeen inscriptions practically all but one as unauthentic, namely the one bearing the date 867 A.D.[5] Kaye states that the two earliest known Hindu inscriptions that contain complete sets of the ten numerals are of 1050 A.D. and 1114 A.D. According to the above, the earliest period of the undoubted use of our notation in India is the ninth century of our era. If the one inscription by which the ninth century is fixed turns out to be unreliable, then we must fall back on the tenth century as the earliest period.

Some writers have ascribed a knowledge of our notation to the astronomer Aryabhatta, early in the sixth century. L. Rodet[6] does so on the ground that Aryabhatta's rule for root-

[4] *Journal Asiatique*, 6 S., T. 1., Paris, 1863, pp. 27–79, 234–290, 442–529.

[5] G. R. Kaye, *Journal and Proceedings of the Asiatic Society of Bengal*, N. S., Vol. 3, 1907, pp. 485–487.

[6] *Loc. cit.*, p. 493.

extraction implied a use of the principle of local value. "Always divide the part that is not square by twice the root of the square, after having subtracted from this squared part the square of the root: the quotient is the root to the next term." Aryabhatta gives no illustrative examples. Rodet's inference does not follow, since the rule applies to all notations. Kaye points out that Theon of Alexandria gave such a rule, yet did not use a notation with place-value.

The second argument, that the early Hindus used the abacus, is rejected by Kaye, for the reason that there is no reliable evidence to support the claim. It has been held that it was the use of the abacus which, most likely, suggested the principle of local value.

The third argument, regarding the testimony of Arabic writers, reveals in some parts the strength of Kaye's contention of a non-Hindu origin and in other parts its weakness. Kaye shows conclusively that through a mistranslation, I. Taylor and M. F. Woepcke, and their followers, have ascribed to the Hindus the use of mathematical processes in early centuries, when, as a matter of fact, there is no evidence whatever to show that the Hindus actually used these processes at so early a date. This historical error arose according to Kaye in the mistranslation of the word *hindasi*. Woepcke admits that ordinarily this word signifies "geometrical," "measure," but asserts that this interpretation seemed impossible when used in connection with an explanation of the rule of "double false position" and the process of "casting out the nines," for the reason that these processes are purely arithmetical[7] in nature. Because of the resemblance of *hindasi* to the word *hindi* or "Indian," Woepcke concluded that with the particular authors in question *hindasi* meant "Indian," and that, therefore, the "double false position" and "casting out the nines" were known to the early Hindus. The latter would seem to imply the use of our notation. But Kaye was able to show that a geometrical interpretation of the passages in question was not only possible, but had actually been found in Arabic books.[8] Moreover, authorities on the Arabic language declare that *hindasi* can not mean *hindi*. Hence, says Kaye, Woepcke's inference that the early Hindus used the method of "double false position" and the process of "casting out nine" is wholly without foundation.

[7] M. F. Woepcke, *Journal Asiatique*, 6 S., T. 1., Paris, 1863, pp. 505, 511.

[8] G. R. Kaye in *Jour. and Proceed. of the Asiatic Society of Bengal*, Vol. 7, 1911, pp. 806–811.

Kaye admits that *hindi* means only "Indian" and that there are Arabic authors who speak of "Indian" numerals and methods of computation. Some light on the probable Hindu origin was obtained only a few years ago,[9] when a passage from the Mesopotamian scholar, Severus Sebokht, indicated that in the latter half of the seventh century the nine numerals were known in Arab lands and were attributed to the Hindus. Hurt by the alleged arrogance of certain Greek scholars, Sebokht praises the science of the Hindus and speaks of "their valuable methods of computation. . . . I wish only to say that this computation is done by means of nine signs." Unfortunately, he leaves it to us to guess whether or not he used the zero. The passage, written about 662 A.D., is the earliest reference that has been found outside of India to our numerals.

About two centuries after Sebokht, appeared the famous arithmetic of the Arab Alchowarizmi. The Arabic original is lost, but a Latin translation has come down to us under the title "Algoritmi de numero Indorum." While this title refers to Indian numerals, they are not actually used in the book. A book on the astronomical tables of Alchowarizmi that was written by Muhammed ibn Ahmed el-Bîrûnî (973–1038) was translated into Hebrew by Rabbi ben Ezra, who says in his introduction that a Hindu astronomical work had been translated into Arabic and that, after the time of Alchowarizmi, "scholars do their multiplications, divisions, and extraction of roots as is written in the book of the [Hindu] scholar which they possess in translation."[10] Other Arabic authors who in the titles of their texts refer to the Hindus are enumerated by Kaye.[11] Thus, about 987 A.D. appeared "The great Treatise on the Table relating to the Indian Calculus." Soon after came "The Principles of the Indian Calculus," and about 1030 "The satisfactory Treatise on Indian Arithmetic." There were two works, both bearing the same title, "Indian Arithmetic," one of the ninth century, the other of the tenth. A Latin text, attributed to Abraham, a Jew of whom little is known, is entitled "Liber augmenti et diminutionis vocatus numeratio divinationis, ex eo quod sapientes Indi posuerunt." The Italian Leonardo of Pisa, after traveling in Egypt, Syria, Greece, Sicily, wrote in 1202 his *Liber abbaci* in which he calls our

[9] M. F. Nau, *Journal Asiatique*, S. 10, Vol. 26, 1910; D. E. Smith and J. Ginsberg, *Bulletin Am. Math. Society*, Vol. 23, 1917, p. 368.

[10] See D. E. Smith, "Rabbi ben Ezra and the Hindu-Arabic Problem," *Am. Math. Monthly*, Vol. 25, 1918, p. 103.

[11] G. R. Kaye, *Journal and Proceedings of the Asiatic Society of Bengal*, N. S., Vol. 7, 1911, pp. 814–816.

numerals with the zero "figuræ Indorum." The Byzantine monk, Maximus Planudes (1260–1330), wrote an "Arithmetic according to the Hindus." The evidence from these and some other texts that we have omitted, in favor of the Hindu origin of our numerals, is not so strong as one might think. In some cases no Hindu symbols are actually employed by the authors; the arithmetic and algebra set forth do not seem to bear Hindu characteristics. Kaye suspects that the word "Indian" was often incorrectly applied. Yet this testimony, as a whole, comes with a force that is difficult to break.

Kaye has sought light on the history of our numerals in other studies. The successive units of our notation increase from right to left. Thus, we write the present year 1919, and not 9191. Therefore, our notation was probably invented by people with a right to left script and not by the Hindus whose script is from left to right. Kaye concedes that this argument is weakened by several considerations; thus, it is known that certain scripts have reversed their direction.

Again, Kaye points out that an "Old Indian" notation without the zero was used in India as late as the twelfth and thirteenth centuries. The form of the symbols with the zero, used in India, differed so widely from the old forms without the zero used there, that the former seem to have had an independent origin and to have been imported into India.

Let us now examine the arguments put forth by the Parisian scholar, Carra de Vaux. He quotes a well-known passage from the Arabic historian Masoudi writing in 943 A.D., giving a legend on creation which De Vaux recognizes as one due, no doubt, to the Neoplatonists in Persia.[12] This legend ascribes an Indian origin to our numerals. De Vaux's contention that the belief in the Indian origin, held by modern writers on the history of mathematics, rests simply upon this legend, is hardly in accordance with fact. Too indirect or circumstantial to be convincing is de Vaux's next point. He says that the Arabic author Albiruni (died 1038) must have drawn his information about Indian numerals from the above named legend, for otherwise he would not have given simply a general statement, but would have followed his usual custom of giving almost overscrupulously precise and detailed accounts.

We have seen that Woepcke erroneously attributed to the Arabic word hindasi the significance of *hindi* or "Indian," and consequently drew some wrong conclusions. De Vaux argues

[12] See Carra de Vaux in *Scientia,* Vol. 21, 1917, p. 274. The quotation from Masoudi is given in *Jour. and Proceed. of the Asiatic Soc. of Bengal,* N. S., Vol. 7, 1911, p. 812.

the other way, namely, that *hindi* does not mean "Indian," but means hindasi or "measure," "geometry," "arithmetic." Hence, when Arabic authors speak of *hindi* numerals, they do not mean "Indian numerals." The only support advanced for this unusual and strange interpretation is that an Arabic writer of the ninth century asks the question, "who is the inventor of the *hindi* figures," implying that he did not know the answer. It is possible that the question might have meant "who *in India* is the inventor of the hindi figures." De Vaux states that the Arabs did not ascribe the abacus to India; it is called *takht*, which is said to be Persian. De Vaux conjectures that the Arabs got the numerals with the zero from the Persians, who, in turn, got them from the Neoplatonists or Neopythagorians of Greece. On this hypothesis it is easier, he says, to explain the diffusion of numerals among the different nations than on that of a Hindu origin. From the Greeks they naturally spread to the Latins (Bœthius, fifth century) and Persians, and from the Persians to the Arabs and Hindus. From the Arabs the numerals passed to Spain, where Gerbert found them in the tenth century. De Vaux's suggestions as to the parts played by Bœthius and Gerbert do not seem to give proper weight to the numerous researches on the authenticity of manuscripts and are open to grave doubts. In fact, De Vaux and Nicolaus Bubnov entertain opposite views with regard to the geometry of Bœthius, particularly the part which contains the account of the nine numerals. Bubnov[13] concludes that it was written in the eleventh century, while De Vaux assigns it to the fifth. Bubnov gave a preliminary exposition of his hypothesis on the origin of our numerals in his 1899 edition of Gerbert's mathematical works. A fuller treatment followed in his book, "The Arithmetical Independence of European Culture," which appeared in Russian in 1908 and was translated into German in 1914. In the same year 1908 he issued in Russian another publication, "Origin and History of our Numerals," We have not enjoyed the opportunity of consulting his last work directly, but a rather full synopsis is given in the *Fortschritte der Mathematik*, 1908, pp. 53, 54. Philological studies lead Bubnov to deny the Hindu origin of our numerals, to claim that in the tenth to the twelfth centuries Europe possessed the modern positional arithmetic, though clothed in the form of the abacus with columns and marked reckoning counters. Bubnov holds that these counters marked with ancient symbols (the progenitors of our numerals) had superseded the older unmarked counters. He points out the existence of a counter which stood for zero (rotula supervacua) and claims that our modern Euro-

[13] See *Fortschritte der Mathematik*, Vol. 38, 1907, p. 62.

pean numerals have no connection with India. Thus he claims that Europe possessed the modern positional arithmetic in *instrumental* form, the instrument being an abacus with columns and marked reckoning counters. He asserts with confidence that the abacus with marked counters was used by the ancient Greeks and Romans, even though (as far as known) no such counter has come down to our time or has been described by writers of antiquity. He says that when *written* arithmetic supplanted instrumental arithmetic, the nine numerals and the zero, which first appeared on counters, finally descended upon the written page, but he has no evidence to support this admittedly clever hypothesis. Nor is he able to point to any European document which contains our nine numerals and the zero as early as they are found in India. Of course, Bubnov has a perfect right to set up hypotheses of his own,but his writings display an inclination on his part to parade unproved hypotheses in the guise of fairly well established facts. That his contentions should be viewed merely as unproved hypotheses appears also from the comments made by Sintzov,[14] Smith and Karpinski,[15] Paul Tannery[16] and G. Eneström.[17]

Summary

The following are the outstanding facts:

1. The earliest reliable record of the use of our numerals with the zero is an inscription of 867 A.D. *in India.*

2. The validity of the testimony of early Arabic writers ascribing to India the numerals with the zero is shaken, but not destroyed.

3. There is not a scintilla of evidence in the form of old manuscripts or numeral inscriptions to support the Greek origin of our numerals.

4. At present the hypothesis of the Hindu origin of our numerals stands without any serious rival. But this hypothesis is by no means firmly established.

As a by-product of the discussion of recent years we must admit that, on the evidence presented, the claim that our numerals and the zero were used in India as early as the fifth century must be abandoned; our earliest apparently reliable evidence belongs to the ninth century. We must also abandon the claim that the early Hindus used the abacus, the rule of "double false position," and the process of "casting out the nines." These corrections are due to G. R. Kaye.

[14] *Fortschritte der Mathematik*, Vol. 39, 1908, p. 54.

[15] Smith and Karpinski, "Hindu-Arabic Numerals," 1911, p. 65.

[16] P. Tannery in *Bibliotheca mathematica*, 3. Series, Vol. 1, 1900, p. 286.

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COLLOIDS AND LIVING PHENOMENA

By Dr. NATHAN FASTEN

THE UNIVERSITY OF WASHINGTON

IN recent years the colloids have assumed a great importance in all discussions of living matter, so much so that life has often been defined in terms of colloïdal reactions. The protoplasm of the living organism consists essentially of (1) water, (2) crystalloids and (3) colloids, and it might be truly stated that all the complex and unintelligible manifestations of living matter depend, largely, on the delicate interplay of these three substances. Whether there is a vital force—an entelechy—a spirit that directs the wonderful behavior of these chemical combinations is a question which can not be conclusively answered. Certainly the results of physics, chemistry and biology within the last few years have tended to give a materialistic guidance to our conceptions of living phenomena, and many modern physiologists are in agreement with Verworn when he characterizes life as nothing more than a reaction of the proteids (colloids). In any event, it matters very little for this

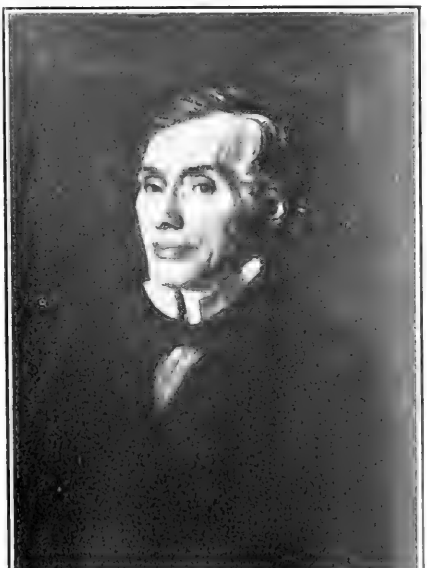


FIG. 1. THOMAS GRAHAM. (From Bayliss.)

discussion whether one's conception of life is "vitalistic" or "mechanistic." All that this paper wishes to present is the rôle played by the colloids in those unique reactions which are commonly designated as "living reactions," or as summed up in the term "life."

The colloids were first investigated by Thomas Graham (Fig. 1) in 1861, who applied the term to those substances which did not readily pass through a dialyzing membrane. To Graham the colloids and crystalloids represented two distinct worlds of matter with no transitions between them, and possessing the following well-defined properties:

Crystalloids

1. Are crystalline substances.
2. Form saturated solutions and crystallize out readily.
3. A saturation point is reached.
4. Are of low molecular weight.
5. Diffuse readily through animal membranes.

Examples of Crystalloids

Sugar, salts, fatty acids, amino-acids, glycerine, etc.

Colloids

1. Are amorphous substances.
2. Do not form saturated solutions and are not found to crystallize out from solution.
3. No saturation point is reached, the solution becomes thicker and thicker finally forming a viscid gum.
4. Are of very high molecular weight.
5. Diffuse but little or not at all through animal membranes.

Examples of Colloids

Gelatine, albumins, glue, gums, etc.

However, we now know that these are but arbitrary distinctions. While it is true that a substance in the colloidal state possesses wholly different properties than the substance in the crystalloidal state, yet it must be recognized that both are states of substances. Albumin, which exists as a colloid may, nevertheless, be obtained in a crystalline form and vice versa. Some of the commonest salts may form colloids. Thus sodium acetate possesses the qualities of a crystalloid in watery solution, while sodium stearate belongs to the colloids. Most of the typical colloids, like the proteids, may be broken down by the digestive ferments to form crystalloids. These ferments

break down the proteids into bodies intermediate between crystalloids and colloids. The proteoses, which are the first products in this metabolism, possess colloidal properties slightly less marked than the protein itself. The peptones, the next products in the breaking down process of protein, although not crystallizable, are, nevertheless, different from colloids and are true electrolytes. These are the steps that bridge the gap between colloids and crystalloids. Biochemists of to-day believe that many substances, perhaps all substances, may exist now in crystalloidal state and then in colloidal state.

This power of change from the colloidal to the crystalloidal state, and *vice versa*, seems to be the very essence of cell life. According to Wells:

> We may look upon cell life as a constant attempt at the establishment of equilibrium, both chemical and osmotic, because the move toward one sort of equilibrium is always against the other. All the food-stuffs—fats, carbohydrates and proteins—are characterized by being colloids when intact and crystalloids when disintegrated, thus:
>
> colloidal proteins $\rightleftarrows$ crystalloid amino acids,
> colloidal glycogen $\rightleftarrows$ crystalloid sugar,
> nondiffusible fats $\rightleftarrows$ diffusible soaps and glycerol.
>
> In consequence of this, if the crystalloids diffuse from the blood into a cell there is at once an excess of this end of the equation, and hastened by the intracellular enzymes, synthesis to the colloid soon occurs to establish chemical equilibrium. Chemical changes in the crystalloids, by oxidation, reduction or hydrolysis, upset this chemical equilibrium and hence further diffusion, synthesis and hydrolysis continue, one upsetting the other continuously. If equilibrium were established we should have no further reactions, and the cells would be inactive. The constant upsetting of the equilibrium is what constitutes cell life.

Perhaps the most interesting characteristic of colloidal substances is their lability. They may readily be broken down and built up into other combinations. Moore in speaking of this lability of the colloids says:

> The whole essence of the colloidal condition is that of a balance of play of energies in the most delicate equilibrium. All the known properties of colloids can be traced to feeble molecular affinities between the molecules themselves, causing them to unite into multi-molecules or "solution aggregates" and to balance between such affinities and similar feeble affinities for crystalloids in common solution with them, and for the molecules of the solvent.

Upon this lability depends the various phases undergone by the colloids in protoplasm.

Colloids are generally divided into the following phases, depending on their more liquid or jelly-like condition:

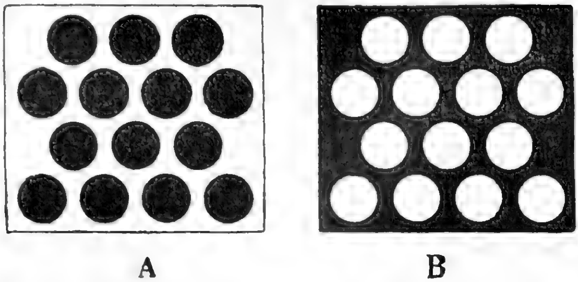
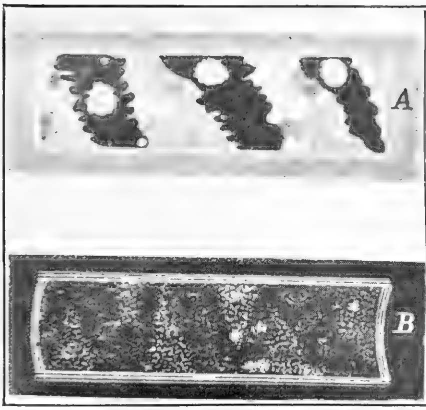


FIG. 2. DIAGRAM ILLUSTRATING PHASES IN COLLOIDAL SYSTEMS. (After Bayliss.) If the black be regarded as solid phase and the white as the liquid phase, then *A* represents a hydrosol, whereas *B* represents a hydrogel.

I. *The Hydrosols* (dispersed states.)—These are pseudo-solutions or fine suspensions. Fig. 2, *A*, represents the typical hydrosol condition.

II. *The Hydrogels* (undispersed states).—These may be either (*a*) the emulsion type, or (*b*) the coagulated or precipitated type (mixtures of emulsions). Fig. 2, *B*, represents the typical hydrogel condition.

In hydrosols the colloidal particles (or multi-molecules) are free and invisible. Each particle is distinctly separated from every other particle and behaves as a single unit or mole-



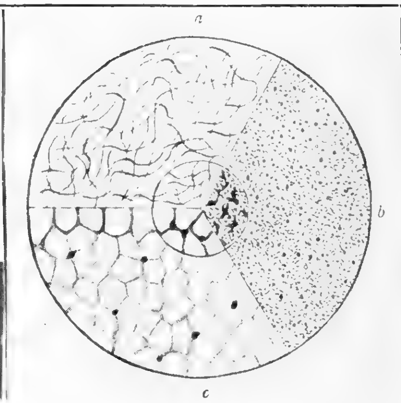


FIG. 3. CELL OF *Spirogyra*. (From Bayliss, after Gaidukov.) *A*, under ordinary microscope; *B*, under ultra-microscope.

FIG. 4. DIAGRAM ILLUSTRATING THE APPEARANCE OF PHOTOPLASM WITHIN THE CELL. (After Bailey.) *a*, fibrillar structure of protoplasm; *b*, granular structure of protoplasm; *c*, foam or emulsion structure of protoplasm.

cule in solution. The particles of the colloids do not enter into true solutions, but usually exist in the form of suspensions which exhibit Brownian movement. This can be clearly seen when colloidal solutions are examined with the ultra-micro-

scope. Figs. 3, *B* and 5, *a–e* show the appearance of the suspended colloidal particles in the living cells of Spirogyra and of the dog's nervous system as seen under the ultra-microscope.

We know that most colloids form suspensions only from still another line of evidence. Substances which enter into true solution alter the freezing point as well as the boiling point of the solvent, but colloids change these points very little if at all.

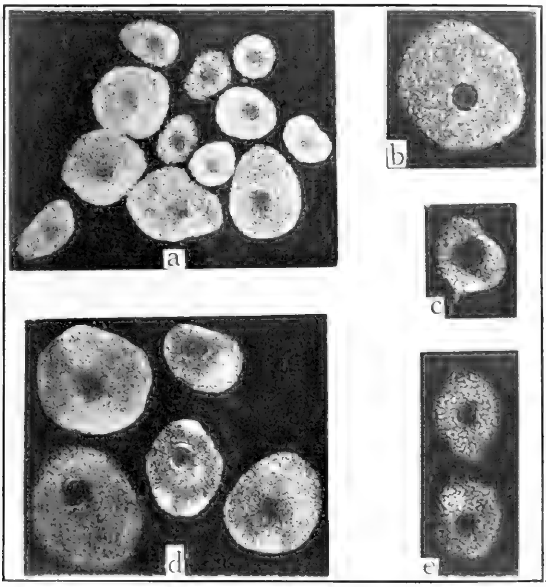


FIG. 5 (*a–e*). LIVING NERVE CELLS FROM THE DORSAL ROOT GANGLIA OF THE DOG AS SEEN WITH THE ULTRA-MICROSCOPE. The colloidal particles within the cells exhibit Brownian movements. (From Bayliss, after Marinesco.)

Furthermore, true solutions, such as formed by crystalloids, exert an osmotic pressure while suspensions show no such behavior. Typical colloids do not exert osmotic pressure, hence form no real solutions.

Some colloids, however, have been recently shown to form real solutions; for instance, Starling has shown that the proteins dissolved in the blood serum possess an osmotic pressure, hence they form true solutions. Pfeffer has also shown by his experiments on gum arabic and glue that these colloids exert osmotic pressure, therefore forming real solutions.

When, for some cause or another, such as a change in the environment of the hydrosol, the multi-molecules of the colloid are aggregated together, a hydrogel is produced. In this condition we have a diphasic system of the colloid, consisting of (1) a very dilute solution of the smaller multi-molecules, and (2) a

more or less solid of huge molecular complexes of the colloid containing comparatively little of the solvent. In forming the hydrogel there has occurred more or less of a setting of the solid colloidal particles.

When this setting of the colloidal particles has occurred in spherules far apart and separated by the fluid medium, then an emulsion is produced. If the setting continues, then a meshwork of the solid particles may be formed, enclosing the liquid phase. In this way a foam or reticulum may be produced, and the meshwork may take on many forms.

It is thus evident that in this manner the various structures found in living cells, foam structures, granular structures, networks, spindle fibers, chromosomes and the like may originate.

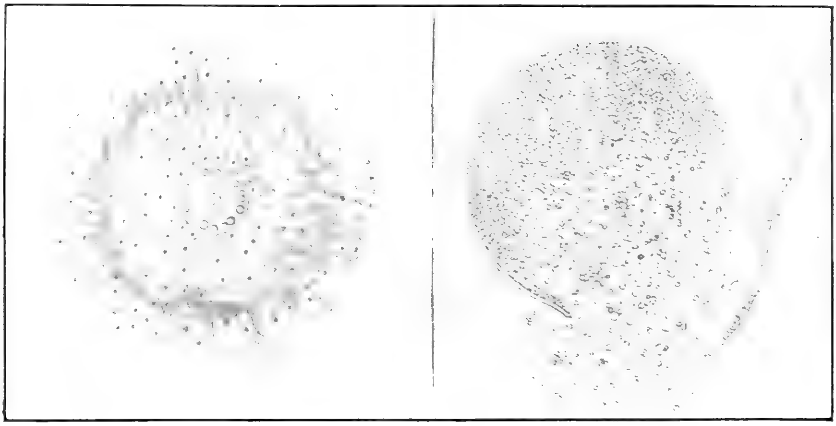


FIG. 6. THE RADIOLARIAN *Thalassicolla pelagica* HAECKEL, showing the foamy, emulsion-like character of the protoplasm. (From Doflein, after R. Hertwig.)
FIG. 7. THE EMULSION-LIKE APPEARANCE OF THE PROTOPLASM OF A RUPTURED OVUM OF *Fucus*. (After Seifriz.)

Fig. 4 illustrates the various appearances which the protoplasm of the cell may assume.

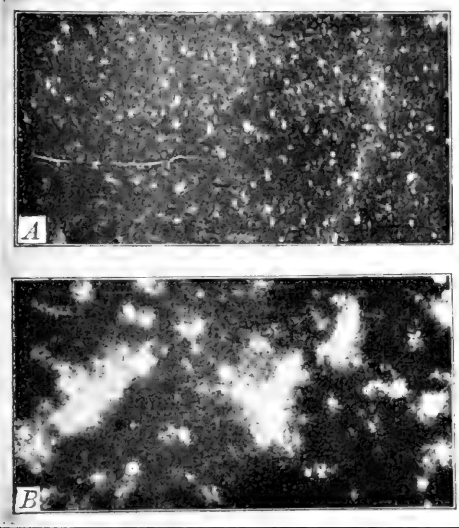
Colloidal gels are of two kinds, (1) reversible, and (2) irreversible.

A reversible gel is one in which a reversal of the condition that produced gelation causes it to return to its original state, the sol state. For example, when gelatin in the hydrosol condition is cooled it solidifies and assumes the hydrogel condition. Upon heating this hydrogel it will again assume the hydrosol condition.

On the other hand, an irreversible gel is one in which a reversal of the condition that produced gelation does not cause the colloid to return to its original condition. For instance,

when the albumen of the white of egg is heated it solidifies and assumes a gel condition. When this gel is cooled it remains unchanged and never reverts to its original hydrosol condition.

All living matter is characterized by its richness in colloids of the emulsion type (Figs. 6 and 7) which present a remarkable degree of reversibility. Protoplasm is really an aggregate of colloids holding water for the most part, in which are con-



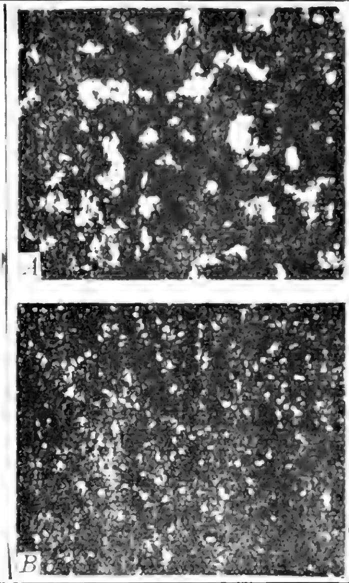


FIG. 8. *A* and *B*. TWO STAGES IN THE CLOTTING OF CASEIN, showing the aggregation of the finer colloidal particles of *A* into the coarser clumps shown in *B*. (From Mathews after Stubel.)

FIG. 9. *A* and *B*. AGGREGATION BY ELECTROLYTES OF THE BLOOD CORPUSCLES OF THE FISH *Scyllium canicula*, suspended in half-normal sodium chloride. (From Bayliss after Mines.) *A*, effect of addition of 0.0008 molar cerium chloride; *B*, effect of addition of 0.08 molar cerium chloride. The dilute solution causes aggregation by reversing the sign of the charge (from negative to positive), of a part of the corpuscles. The concentrated solution causes a rapid reversal of all the corpuscles from negative to the positive sign, causing them to remain suspended.

tained electrolytes and non-electrolytes. Hence, the chemical reactions of protoplasm occur in dilute solutions of electrolytes.

Electrolytes when in solution dissociate into ions, the positive ions, or *cations*, bearing positive charges of electricity, while the negative ions, or *anions*, bear negative charges of electricity. Thus when *NaCl* is dissolved in water, a dissociation of the *Na* and *Cl* ions occurs. The *Na* ions bear positive charges while the *Cl* ions bear negative charges. The *Na* ions are therefore *cations*, whereas, the *Cl* ions are the *anions*. Within recent years it has been found that ions may exist not

only as charged atoms, but as charged groups of atoms (radicals) as well.

Many biochemists and physiologists now believe that the physiological action of many substances depends upon the electrical charges borne by the ionized particles, and not on the chemical nature of the particles themselves.

Colloidal particles have been shown to bear electrical charges. The colloid particle, although consisting of many atoms, behaves as a single charged particle as far as its electrical charge is concerned. In general acid colloidal particles are electro-negative and alkaline colloidal particles are electro-positive. The charged particles induce the opposite charge in the surrounding water or other fluid medium in which they are suspended. If the colloidal particles are charged with positive electricity, the surrounding fluid medium is charged negatively and vice versa. Also, the number of charges in the surrounding fluid is proportional to the surface of the colloidal particle. If by any means (such as heat, electricity, internal chemical changes, etc.), the colloidal particles are thrown together into aggregations, then a reduction in the amount of surface of the particles occurs, bringing about a readjustment in the electrical conditions of the surrounding medium. Conversely, when a change occurs in the electrical state of the medium surrounding the colloidal particles, a readjustment in the latter occurs. For instance, when the density of the charge of particles is diminished aggregation leading to coagulation (Fig. 8, *A* and *B*) is brought about; when the density of the charge is increased a still finer division of the particles is produced (Fig. 9, *A* and *B*). Either change might occur as a result of the chemical changes in the particles themselves or in the conditions surrounding them.

Hardy has made a very extensive study of the electrical properties of colloids. Guyer summarizes Hardy's work as follows:

> Hardy, using a sol of proteid has shown: (1) that a gel is produced by the addition of electrolytes, but not by the addition of non-electrolytes unless they act chemically; (2) that the gelation produced by electrolytes is due to the electric charge carried by the ion, inasmuch as identical results follow the use of an electric current from a battery; (3) that the signs of the electric charges carried by the ions (plus or minus) determine the movements of colloidal particles either keeping them in suspension as a sol or causing them to fall into the gel condition (*e. g.*, a sol having its colloidal particles negatively charged will pass into a gel state if plus ions are added or if the plus electrode of a battery be introduced).

Certain daily events may be interpreted intelligently by bearing in mind the above facts. For instance, the irritability

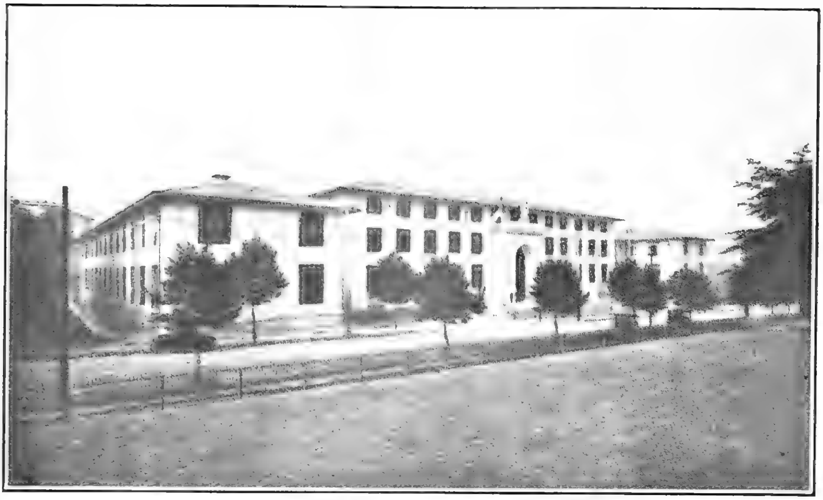
of the human organism depends largely on the state of the colloids in the nervous system. When these colloids go into a gel condition the individual becomes irritable. When this condition is prevented irritability is lost. To take concrete examples:

1. *Mechanical stimulation* such as a shock, push, blow or electrical stimulation would cause neighboring colloidal particles on which they acted to coalesce, thus reducing their surface. Since the colloidal particles are normally positively charged, they induce the negative charge in the surrounding medium. Any reduction in the surface of the colloidal particles releases a portion of the negative charges previously induced in the fluid medium. These released negative charges act on the neighboring colloidal particles, etc. Thus a wave of gelation results, passing over the nerve, with the liberation of negative ions at the end of the process which call the muscles into play, resulting in action.

2. *Stimulation by Light and Ether Vibrations.*—Protoplasm is stimulated by light due to the charges of the electrons in the sun. When these electrons move through the ether they set up vibrations which, when they come in contact with protoplasm, act like ions, setting up a wave of gelation over the colloids in nerves, thereby bringing about a response.

3. *Chemical Stimulation.*—The action of certain chemicals, like chloroform, ether and alcohol on protoplasm may be explained on a similar basis. These substances increase the hydrosol condition, thereby preventing irritability. So long as these drugs are administered the colloidal particles of the nervous system are divided more finely, thereby causing a loss of consciousness. When these substances wear off consciousness returns. The above explains the values of ether and chloroform as anesthetics. The action of alcohol or whiskey during a snake bite may also be explained on the same grounds. Snake poison causes a coagulation of the colloidal particles. Alcohol prevents such precipitation.

On such a basis we can readily understand the rapid changes in the consistency of protoplasm—changes from more rigid conditions to those that are more fluid and vice versa. Only by understanding the reactions of the three substances entering into living combinations, namely, water, crystalloids, and colloids, can we hope to intelligently comprehend such living processes as metabolism, growth, irritability and the like. In a word "life or the life process is a reaction of the colloids," and in order to understand life or the life process the biologist of to-day must give his moments to the study of the colloids.



THE PITTSBURGH EXPERIMENT STATION OF THE BUREAU OF MINES.

THE PROGRESS OF SCIENCE

DEDICATION OF THE PITTSBURGH EXPERIMENT STATION OF THE BUREAU OF MINES

THE new experiment station of the U. S. Bureau of Mines at Pittsburgh, which has been in use for about two years, was formally dedicated to public service on September 29, the dedication ceremonies having been postponed on account of the emergency of war. E. V. Babcock, mayor of the city, welcomed the guests and official delegates and this welcome was responded to by A. T. Vogelsang, first assistant secretary of the interior, who read the following telegram from President Wilson: "Will you not be kind enough to convey my most hearty greetings to the assemblage at Pittsburgh next Monday. I wish that I might be present to express my very deep interest in the work being done by such instrumentalities for the increase of production, the safeguarding of life and the raising of the standard of labor and scientific endeavor. It is a very happy circumstance that with this meeting should be associated the ceremonies connected with the dedication of the new buildings in Pittsburgh of the Bureau of Mines."

William C. Sproul, governor of Pennsylvania, spoke of the importance of the Mining Industry in the state, of the contribution which the Bureau of Mines has made and can make to its continued progress, and pledged the cooperation of the state in every way in helping the bureau to do the things it is necessary and desirable to do in the development of the Pittsburgh station to its full usefulness. He also urged the cooperation of the men who do the work in the industry and the men who have the properties in which the work is done. J. Parke Channing, the representative of the American Institute of Mining and Metallurgical Engineers, discussed the problem of production and distribution in industry and the industrial problems of the day.

The key of the building was formally turned over to Director Van H. Manning by Assistant Secretary Vogelsang, who said that he hoped the key would never lock the building, but be regarded rather as a symbol of the purpose and the function of the bureau to unlock the secrets of nature for the use and benefits of all mankind. Mr. Manning in receiving the key said: "It is indeed to me a very high privilege to accept from you this key to this magnificent structure which has been contributed to the cause of humanity by our Government. It is an honor to be the representative who has been selected to accept this emblem which stands for safety and efficiency in the universal industry and I hereby pledge to you, Mr. Secretary, and to you who represent capital and labor, employer and employee in the mining and allied industries, my allegiance to the cause we represent."

The Pittsburgh station and its work, the development of the Bureau of Mines and the plans of its founder, Dr. J. A. Holmes, are described in an illustrated program published at the time of the dedication. It states that forming a part of the mining division of the Bureau of Mines, the coal mining section has its headquarters at the Pittsburgh Experiment Station, which is centrally situated with respect to the large coal fields of Pennsylvania, West Virginia, Ohio and other nearby states. For the purposes of organization the mining regions of the country are divided into several districts, a mining engineer being placed in charge of the work of the bureau in each district. In addition to the corps of engineers maintained at Pittsburgh under the direct supervision of the chief coal mining engineers, district engineers whose investigations pertain chiefly to coal mining are stationed at Birmingham, Ala., Vincennes, Ind., Urbana, Ill., Seattle, Wash., Golden, Colorado, and McAlester, Okla.

The mine safety section has its headquarters at Pittsburgh with safety stations also at McAlester, Okla.; Vincennes, Ind.; Birmingham, Ala.; Jellico, Tenn.; Seattle, Wash.; Norton, Va., and Berkeley, Calif. Six new all-steel cars have

THE PITTSBURGH STATION FROM THE REAR.

been built to replace the old remodeled cars, three of which, however, are still in use. Five auto trucks are also maintained for training work and for emergency use in the event of mine disaster. Other departments are the fuels section, the electrical section, the mechanical section, the chemical section, the analytical laboratory, the gas laboratory, the gas-mask laboratory, the natural gas research unit, the microscopic research unit, the petroleum laboratory, the explosives chemical laboratory, the metallurgical and metallographic laboratories, and the physical laboratory, the experimental mine near Princeton, Pa., explosive section and the administrative section.

THE BUREAU OF MINES AND JAMES AUSTIN HOLMES

THE work of the U. S. Bureau of Mines, as defined in the legislation creating it, is to conduct scientific and technologic investigations concerning mining and the preparation of mineral substances with a view to the increase of health, safety and efficiency in the mineral industries. Its work has two phases: investigative, to determine the best procedure along these lines; and cooperative, to assist industry in utilizing to the fullest practicable degree the improved practises thus developed. To the latter end it welcomes the cooperation of operators, workmen's organizations, commercial bodies, technical societies, state and other government officials, and every one who is interested in the advancement of the mining and metallurgical industry.

The research branch has charge of investigation which is chiefly carried on in the experiment stations, although a large part is performed in the field. For purposes of technical supervision, there are five divisions of the research work; mining, metallurgical, petroleum, mechanical equipment (which includes the utilization of fuel) and mineral technology.

The operations branch carries on the cooperative work of the bureau that has been initiated by the research branch. The division of mine rescue cars and stations carries on mine rescue and first aid work at actual disasters, trains thousands of miners yearly to perform such work, and promotes interest in safety in mining through every means at its command. The division of education and information facilitates the making available to the mining public of the work done by the other branches, through publication of researches and statistics, exhibits, motion pictures, and the dissemination of information as to the laws governing the mining industry.

The foundation of the bureau was due in large measure to the efforts of the late Professor James Austin Holmes. When state geologist of North Carolina, he was chosen to organize the department of mines and metallurgy of the Louisiana Purchase Exposition at St. Louis. His creative imagination saw there an opportunity to secure results of permanent value through the analyzing and testing of the coal resources of the United States and of structural materials in connection with the exhibition, and this was done under the direction of a commission of which he was a member. After the close of the exposition the work was continued under his charge. The testing plant was subsequently transferred to the Jamestown Exposition and finally to the Arsenal grounds at Pittsburgh. In 1907 the technologic branch of the U. S. Geological Survey was organized with Dr. Holmes in charge.

At that time the United States had the unenviable distinction of

JOSEPH AUSTIN HOLMES,

The first director of the Bureau of Mines

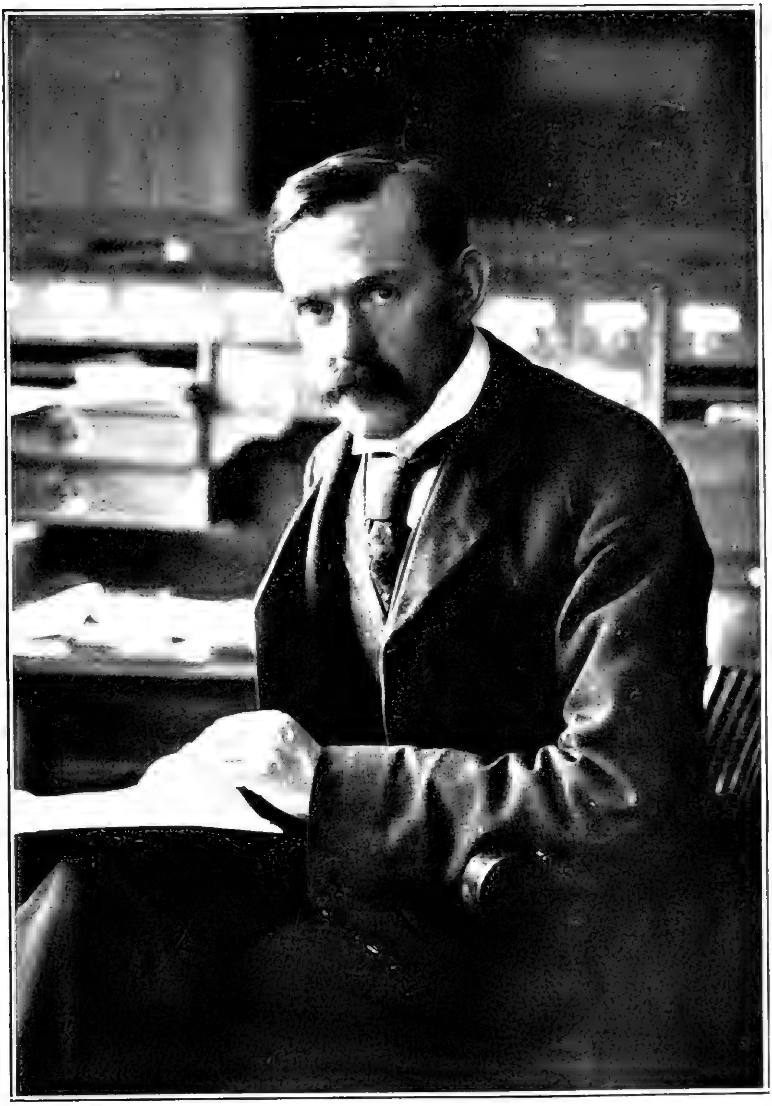
being not only the most prodigal nation in the expenditure of national resources, but of the lives of its citizens as well. Its leading place in the production of all the principal mineral substances was accompanied by a wanton loss of life and of health. In 1907 there was an unusual number of mine explosions, and the result was a general movement to take steps to prevent the needless loss of life. These culminated in the creation of the Bureau of Mines, in 1910, for the purpose of increasing health, safety, and efficiency in the mining industry. Dr. Holmes was appointed director and retained the position until his untimely death in 1915.

Starting the work at Pittsburgh placed it in the center of an important mining and metallurgical region. Though the work of the bureau was at first housed in temporary and unsuitable quarters, Dr. Holmes had a vision of a great experimental station for mining, where all kinds of accidents could be studied, and methods developed for their prevention, which miners and operators alike could feel was their station and could come to for information and education. It was also his conception that this station should help to stop the waste in mining resulting from the inefficient methods employed and the excessive competition in the coal industry. To this end he foresaw the need for research laboratories for chemical and physical investigation of gases, explosives and mineral substances, and equipment for the testing of mine lamps and other machinery, and finally, of the establishment by the bureau of such agencies as would result in the training in the use of rescue apparatus and in giving first aid to the injured. The fruition of Dr. Holmes's work is the experiment station which has now been dedicated.

THE BRITISH NATIONAL PHYSICAL LABORATORY AND SIR RICHARD GLAZEBROOK

As Dr. J. A. Holmes was mainly responsible for the establishment and development of the Bureau of Mines and Dr. S. W. Stratton is for the Bureau of Standards, so in England Sir Richard Glazebrook has been director of the National Physical Laboratory since its inception. He retired on September 18, his sixty-fifth birthday, and is succeeded by Professor J. E. Petavel, professor of engineering and director of the Whitworth Laboratory in the University of Manchester.

The London *Times* remarks that "Sir Richard Glazebrook has controlled the fortunes of the National Physical Laboratory from its small beginnings in 1899 to its present great place in the scientific organization of the nation. It was first intended merely to carry out investigations required in connection with the manufacture and testing of instruments of precision, and in 1902, when it was moved to new buildings at Teddington, it had only two departments and a staff of twenty-six. It has now seven scientific departments, a secretariat, and a staff of over 600 persons. These deal with heat, optics, acoustics and molecular physics, with electricity, metrology, engineering, metallurgy, the forms of ships and aerial machines, and aero-dynamics. It gives advice on all questions involving the physical properties of matter, the strength and quality of materials, gauges and standards. During the war it rendered invaluable service. In the financial year ending in March, 1918, the Ministry of Munitions alone paid it £42,000 for work done, and the expenditure was not on manufacture, but merely on examining and testing. Until last year the Royal Society was the



Sir Richard Glazebrook.

Retiring Director of the British National Physical Laboratory.

governing body of the laboratory, and conducted its affairs with the assistance of a general board of thirty-six members, of whom twelve were nominees of industrial and commercial institutions. But the financial responsibility was heavy and increasing, and from April 1, 1918, the Department of Scientific and Industrial Research took over the burden, but assumes only the control necessary for an accounting authority. The *Times* says "Sir Richard will hand over to his distinguished successor, Professor Petavel, not only an institution of great and growing usefulness, but a tradtion of harmonious cooperation between science and industry. He has provided the new Department of Scientific and Industrial Research with a working organization sufficient to justify their existence, and with a model on which we may suppose that their most successful creations, the Industrial Research Councils, have been formed."

SCIENTIFIC ITEMS

We record with regret the death of Dr. Cyril Hopkins, head of the department of agronomy of the University of Illinois, and of Dr. August Hoch, formerly director of the Psychiatric Institute on Ward's Island, New York.

Dr. W. H. Herdman, professor of zoology in the University of Liverpool, who has been general secretary of the British Association for the Advancement of Science since 1903, has been elected president of the association.—The Willard Gibbs gold medal was presented on September 26 to Professor William A. Noyes, director of the department of chemistry at the University of Illinois, for special work in chemistry for the government performed during the war.

Mr. Arthur Balfour has been nominated for election as chancellor of Cambridge University, in succession to his brother-in-law, the late Lord Rayleigh.—William McDougall, reader in mental philosophy in Oxford University, has been elected professor of psychology at Harvard University to fill the chair vacant by the death of Hugo Münsterberg.—Mme. Curie has been appointed professor of radiology in the Warsaw University.

Professor Vito Volterra, who holds the chair of mathematical physics in the University of Rome and is a member of the Italian Senate, will deliver a series of Hitchcock lectures at the University of California from October 6 to 17. This will be the second series of Hitchcock lectures this semester, Professor W. J. V. Osterhout, of Harvard University, having just completed the first series on the general subject, "Fundamental life processes." Professor Volterra will lecture on "The propagation of electricity" and "Functional equations."

THE SCIENTIFIC MONTHLY

DECEMBER, 1919

THE MECHANISM OF EVOLUTION
IN THE LIGHT OF HEREDITY AND DEVELOPMENT[1]

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THE general theory of organic evolution undertakes to explain by natural processes the origin of the existing world of living things, and in particular it seeks to account for three classes of phenomena, namely, (1) The diversities (varieties, species, genera, etc.) of the living world; (2) progressive organization (increasing complexity of structure and function) from the lowest to the highest organisms and (3) the fitnesses (adaptations, etc.) of living beings. Its aim is nothing less than a mechanistic explanation of the origin, development and present state of the entire world of life; this is really an enormous undertaking and it is not surprising that this ultimate objective has not yet been reached, indeed it is probable that it may never be fully attained; but at least the problems of organic evolution are in process of being more clearly defined and some promising beginnings have been made toward their solution. To insist, as some have done, that the theory of evolution has failed because it has not yet solved all of these problems is to underestimate both the magnitude of the problems concerned and the progress which has been made toward their solution; to reject evolution, as others have done, because the problems are too great to be solved by the scientific method, is to renounce the slow and sure progress of science in favor of pure speculation and mysticism in which no progress at all is possible.

Scientists no longer discuss the question as to whether evolution has occurred, but there is much conflict of opinion as to how it has occurred. The fact of evolution stands fast; present

[1] William Ellery Hale Lectures before the National Academy of Sciences, Washington, April 16 and 18, 1917.

uncertainties, hypotheses and theories concern only the factors. Unfortunately this distinction between fact and factors has not been appreciated by many persons who are not students of this subject and consequently they have assumed erroneously that doubts as to the latter implied uncertainty as to the former. The two great systems of evolutionary philosophy, known as Lamarckism and Darwinism, are hypotheses as to the factors of evolution, and, if one or both of these should prove to be erroneous, it would not shake our confidence in the truth of evolution itself.

The mechanism of organic evolution is an enormous subject and many phases of it I should be unable to present except in a superficial manner; fortunately a comprehensive discussion of this topic is rendered unnecessary by the lectures of my immediate predecessor in this series.[2] I shall therefore limit my discussion to experimental and analytical studies of inheritance and development in their bearings on evolution. Even in this more limited area I must draw largely upon the work of others. My own researches have lain very largely in the domain of cellular biology and doubtless to many naturalists of the old school this field seems very remote from that of the origin of species. But in biology all roads lead to evolution and, though some of these are highways and others only by-paths, the inhabitant of any quarter of this world may come to its center by the road which passes his own door—by which simile I hope to forestall the criticism that my own field of work does not lie on certain main highways of evolution and that I do not attempt in these lectures to traverse all the routes that lead to the Eternal Theory.

I. Evolution, Historical and Experimental

In the development of science there has been a general movement from the methods of observation and description to those of analysis and experiment. Biology as a whole is just now making this transition; physiology has long been experimental, but only within the past quarter century have experimental methods been used extensively in the study of morphology, embryology, heredity and evolution. Biology is no longer a study of living things with the life left out, and evolution is no longer merely a study of the beaches where the tides of life have been. For long, evolution was studied and regarded merely as a past process which had flourished mightily

In the dark backward and abysm of time

but which had practically ceased to-day. As a historico-

[2] Henry Fairfield Osborn, "The Origin and Evolution of Life."

scientific subject its results were studied and their cause surmised—all at very long range. As a past process it was approached only through the static branches of biology, such as Classification, Morphology, and Paleontology.

1. *Classification and Evolution*

To Darwin and his contemporaries evolution was largely a question of species and their origin, although it is true that Darwin laid much broader foundations for his theory than can be found in Classification alone, extending them into almost every field of biology and thus anticipating many recent developments of this subject. Nevertheless, to most naturalists of that period the transmutation of species seemed to be a problem for the systematists. It was in his famous "Essay on Classification" that Louis Agassiz attacked the new theory, and it was in the field of systematic botany that Asa Gray gave it such effective support. I remember with what scorn I once heard Cope say of Weismann, "He does not know species, and yet he presumes to discuss their origin." Now we ask, "Does any one know species?" and we look to the experimentalist for an answer, for the geneticist has shown how extraordinarily complex a species may be. Now we recognize that the evolution of a Linnean species is a problem akin to the origin of genera or larger groups, to be approached only by analogy and speculation. The experimental evolutionist deals with variations, mutations, elementary or incipient species which can be studied effectively only in pedigreed cultures.

2. *Morphology and Evolution*

The earlier morphologists studied the structure of various organs and systems in different species and in different stages of individual development and guessed more or less shrewdly as to the manner in which these structures had evolved. It is amusing now to recall how almost any group of organisms could be shown, by those who had made a special study of that group, to be ancestral to many other groups and how easy it was to construct "phylogenetic trees" or to explain the origin of particular structures by pure speculation. Whenever modifications of a structure could be arranged in a nicely graded series it was assumed that the actual course of the evolution of this structure had been determined, and not infrequently it seems to have been assumed that the course of evolution revealed its cause. Now we know that the minor changes in evolution do not always occur in a nicely graded series, but sometimes by sudden or dis-

continuous changes, while the course of evolution reveals only the direction and area in which its causes must operate, but not the causes themselves.

3. *Paleontology and Evolution*

Of all students of evolution the paleontologist has the most direct evidence as to its general course in the past but he has also the most indirect and uncertain means of determining its intimate causes, for he is farthest removed from it as a living process which can be dealt with experimentally. Consequently for the paleontologist as well as for the systematist and morphologist the methods and causes of evolution afforded a fertile field for an active imagination and as a result almost every possible theory was proposed, but none were demonstrated. The subject appealed to imagination, but not to verification.

4. *Experimental Evolution*

As long as evolution was regarded merely as a past process it could be studied only as an historic phenomenon. The recognition of evolution as a present process makes it at once an experimental as well as an historical science, and its problems are not merely those of the systematist, morphologist and paleontologist, but also those of the geneticist, embryologist, cytologist, physiologist, and bio-chemist. In short all branches of biology now center in this great theory. Furthermore, the only possible method of really determining the causes of evolution and of demonstrating the mechanism involved is by means of experiments.

(*a*) *Deals only with Diversities or Minor Changes.*—The study of contemporary evolution must of necessity deal with relatively minute changes in organism, with the production of mere diversities. The greater steps in evolution, such as the origin of species, genera and larger groups, and all progressive evolution, can not be dealt with experimentally unless such experiments are continued for long periods of time or unless artificial means are found of speeding up the evolutionary processes. Indeed it may be objected that until these minor changes have accumulated so that they actually give rise to new species comparable to those existing to-day in nature, we shall not be sure that they are real steps in evolution,—the materials out of which the many diverse forms of animals and plants have come into existence. Unfortunately this is only too true, and consequently evolution in its larger aspects is now and must long remain a theory rather than a demonstration, and yet the evi-

dences that some of these minor changes, such as variations and mutations, are first steps in the making of species and still higher groups is so extremely probable that it would be unreasonable to deny it. It is at least a probable and reasonable hypothesis and we know of no other which is either reasonable or probable.

(*b*) *Rise of Experimental Biology.*—During the last two decades of the nineteenth century the experimental method began to be used in the study of ontogeny and phylogeny and an indirect though most important result of such experiments was the introduction of a more critical spirit into morphology and a growing dissatisfaction with speculations on the course or cause of phylogeny. For some years there was conflict between the "pure morphologists" and the "experimentalists" as to the relative value of observation and experiment, but now so completely has our point of view changed that morphology as a purely observational study of dead "material" has almost ceased to exist, and in many institutions professorships in morphology have become professorships in experimental zoology or botany. And yet there is no magical power in experimental methods which renders the older methods of observation antiquated or useless. As a method of investigation experiment alone is no better and probably is not as good as observation alone; it is only when experimental methods are used to supplement observational ones that the best results are obtained.

(*c*) *Iconoclasm of Experimentalists.*—The experimental method, whether in morphology, embryology, or evolution is "nothing if not critical." In the first enthusiasm for the new method its advocates began by discrediting or discarding conclusions based upon mere observation and reflection. But scientific theories are not necessarily false because they have been come at by observation or logic; clear thinking is essential to scientific progress as well as careful experiments, and brains as well as eyes and hands play an important part in the discovery of truth. Nevertheless there is probably no other scientific doctrine which shows a greater need of caution, criticism and experimental confirmation than does the theory of evolution. In evolution no less than in other scientific fields frequently the most complex hypotheses are devised to account for things which have no real existence, as for example attempts to explain the hereditary transmission of acquired somatic characters, the telescoping of phylogeny into ontogeny, the transformation of one adult organism into another, etc. Science sometimes becomes so lumbered up and confused by many false theories that the best way of

advancing knowledge is by clearing the ground of errors, and this is especially true of evolutionary theories because of their appeal to imagination and their difficulty of verification.

(*d*) *Extravagant Hopes of Experimentalists.*—In the first enthusiasm over the application of experiment to the problems of evolution many extravagant hopes and predictions were made. Not only species, but even whole faunas and floras were to be artificially made "while you wait." But organisms have shown themselves to be wonderfully stable and resistant to change. Modifications of all sorts can be produced but few if any of these are inherited. The living thing which is delicate and plastic beyond all comparison is yet remarkably stable and stubborn. The results of experimental evolution as compared with the anticipations of twenty years ago have been distinctly disappointing; and yet progress has been made, and in particular many facts are more definite, many ideas more clear and many old theories have been shown to be untenable while a few have been more firmly established than ever before. Probably more progress has been made since the year 1900 in understanding the factors of evolution than in all previous centuries. And this is true largely because of the epoch-making work which has been done during the past fifteen years in bringing to light the factors of individual development.

5. *Genetics and Cytology—the Recent Lines of Progress*

The two fields in which our knowledge of the causes of evolution has made the greatest and most substantial progress within recent years are genetics and cytology, the one dealing with the inherited characteristics of successive generations of individuals, the other with the cellular bases of these characteristics in the germ cells and the transformations which these undergo in development; the former with the analysis of the developed organism into its constituent characters, the latter with the analysis of the germ cells with especial reference to the material basis of heredity. Although at first these two lines of work seemed very distinct the researches of the past fifteen or twenty years have shown that they are most intimately related and each has shed a flood of light upon the other. In the combination of these two lines of research so totally different in methods and apparently so unrelated in results, our knowledge of the methods and causes of evolution has been greatly extended. For the first time we know pretty definitely where to look for evolutionary changes, for the first time we are getting at the real mechanism of evolution.

Since the rediscovery in 1900 of the long-forgotten principles of inheritance, which were first made known by Mendel in 1866, remarkable progress has been made in the field of genetics—indeed almost all that is known concerning the exact manner of hereditary transmission has been learned since that year, and it is probable, as Morgan has said, that the fundamental principles of such transmission have already been discovered. The great and almost endless problems which stretch out before the geneticist have to do with a more minute study of the factors or causes of hereditary transmission. In similar manner the grosser facts as to the structure and development of the germ cells and as to the transformation of the fertilized egg into the embryo and adult are well known, but we have made the merest beginning in the study of the causes of this development and of the exact manner in which the germinal organization is transformed into developed characters. Development is indeed a vastly greater and more complicated problem than heredity, if by the latter is meant merely the transmission of germinal units from one generation to the next.

Thus the study of genetics, cytology or of any other science repeats the same general process which has characterized the study of evolution itself,—the outstanding facts are first established with relative ease, the factors are determined only after prolonged research. Furthermore the discovery of "the cause" of any phenomenon evermore leads to new inquiries as to the cause of this cause, so that research is never finished and knowledge is never complete.

II. Ontogeny and Phylogeny

Intimate Relations of the Two

Ontogeny or the origin of individuals and phylogeny or the origin of races are two different aspects of one and the same thing, namely organic development. There is a remarkable parallelism between the two, and in particular the factors or causes of development are essentially the same in both. Phylogeny is a present process as certainly as is ontogeny. Just as the earth rotates on its axis, revolves in its orbit and the whole solar system moves through space, so organisms undergo embryonic development, specific development and phyletic development, all being parts of one great process. All detailed study of evolution is necessarily a study of successive generations of individuals, and all analytical or experimental study of the causes of evolution resolves itself into a study of the factors involved in the genesis of individuals; there is no other possible

method of approaching the problem. For this reason the student of ontogeny is especially well fitted to deal with the factors of phylogeny. The study of the factors involved in the genesis of individuals under various conditions of inheritance and environment reveals all that can certainly be known regarding the methods and causes of the evolution of races and species.

1. *Development is Real and not Illusory*

Ontogeny or the development of an individual from the egg to the adult condition consists in progressive, coordinate differentiation of both structures and functions. To a certain extent differentiations are already present in the germ cells, but during the course of development their number is greatly increased. This increase in differentiation is caused by modification of previously existing differentiations, by transformation rather than by formation *de novo,* by evolution rather than by creation. New things appear in the course of ontogeny because of new combinations of things already present, just as new chemical substances with new qualities appear as a result of new combinations of elements.

In similar manner evolution is progressive diversification and adaptation. New species, new adaptations, new forms and new functions appear in the course of evolution because of new combinations of characters already present, or rather of the elements out of which characters are built. If any Mendelian of the stricter sort is inclined to question this statement and to affirm that characters or their germinal factors come out of any combination exactly as they went into it and that they have therefore suffered no permanent change, let him consider that any permanent change or mutation of a germinal factor or gene must consist in some new combination of the elements which go to make up the factor itself. For the very possibility of any change or mutation proves that the thing which changes is composed of more elementary units, and this is true not only of organisms, characters and germinal factors, but also of molecules and atoms. Those things only can be absolutely changeless which are absolutely elemental, and *vice versa,* those only are absolutely elemental which are absolutely changeless. *Organic evolution must of necessity consist in new combinations of the parts of which organisms are composed, whether those parts be organs, characters, genes, molecules or atoms.*

Neither ontogney nor phylogeny consists in making visible what was present but invisible before, much less is it a mere simplification of an original complex by a sorting out of certain

characters or factors of characters. It will be shown in a later section that ontogeny does consist to a certain extent in sorting out different materials present in the egg and in the isolation of these materials in different cells, but there is also a progressive formation of new materials during the course of development; there is in development real increase of complexity in which new characters appear by a process of "creative synthesis"; new combinations of the same old elements give rise to new qualities, new forms, new functions. In short, development is real and not illusory, and what is true of ontogeny in this respect is equally true of phylogeny.

2. *Development is Progressive and not Retrogressive*

Of all false theories and erroneous opinions one of the most far-reaching and misleading in its effects is that which may be called the inverted view of development, a view which regards the adult organism as the starting point in ontogeny or phylogeny and which then attempts to explain the transfer of developed characters from this to the germ. This inverted view of development is responsible for almost all of the false theories of development and evolution which now incumber the science of biology.

(*a*) *Inverted View of Ontogeny.*—Before Weismann a false trend was given to theories of development by neglecting or misconstruing one of the most elementary facts of ontogeny, viz., that development proceeds from the egg to the mature organism and not in the reverse direction. It was known, of course, that the egg produces the hen, but it was believed that the hen in turn produces other eggs, so that the life cycle was thought to consist of a progressive phase from egg to hen and a regressive phase from hen to egg (Figs. 1 and 2). It seemed evident that the mature organism manufactured the germ cells, and consequently, it was supposed that characters of the adult organism could be "reflected on" or condensed in the germ cells and then reappear in the next generation. Darwin's hypothesis of "pangenesis" made this general conception more precise by assuming that every cell of the body contributes particles or gemmules to the formation of the germ cells.

Based on Erroneous Cell Theory.—This inverted view of development, namely that mature organisms make the germ cells, is the result in large part of erroneous opinions as to the manner of origin of cells in general and of germ cells in particular. From the time of the work of Casper Friedrich Wolff (1759) to that of Remak (1841) it was maintained that "ves-

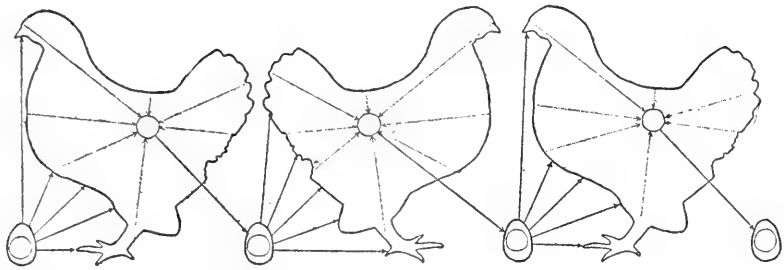

FIG. 1. DIAGRAM SHOWING THE ERRONEOUS VIEW THAT THE BODY OF HEN PRODUCES THE EGG (dotted arrows), while the latter in turn produces the body of the hen but not the egg.

icles" or cells appeared as droplets in a fundamental substance, or "as bubbles of gas appear in fermenting dough." New cells were supposed to appear between the old ones by a process known as "free cell formation." A principal feature of the cell theory of Schwann (1839–41) was that new cells arise in a homogeneous ground substance, the cytoblasteme, "like crystals in a mother liquor." On the other hand Remak (1841) proved that cells arise by division of preexisting cells, but for a long time "free cell formation," or the formation of cells *de novo*, was still maintained to be one of the methods by which new cells arise.

This antiquated conception as to the origin of cells is still responsible for much rubbish in our theories of evolution and development, for even at the present day many theories which grew up under this old conception are still maintained. If earlier evolutionists had known that every cell comes from a preceding cell by division and that it thereafter remains absolutely distinct from other cells, taking into itself no living substance from without but manufacturing its own protoplasm from food substances, there probably would have been no doctrine of "pangenesis," of the "reflection of adult characters on the egg," of the inheritance of developed somatic characters—no inverted views of development, heredity and evolution.

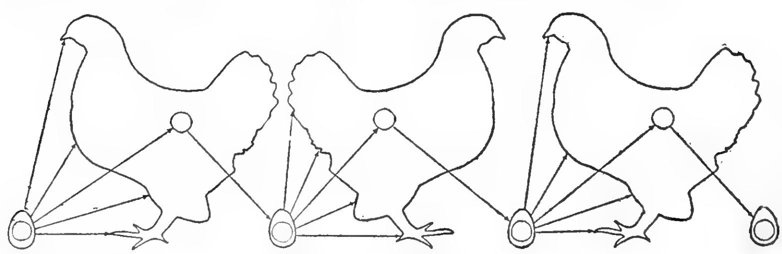

FIG. 2. DIAGRAM SHOWING THE TRUE VIEW THAT THE EGG PRODUCES THE BODY OF THE HEN AND ALSO THE EGG.

The cellular history of development has demonstrated that adult organisms do not manufacture germ cells and transmit their characters to them. Neither germ cells nor any other kind of cells are formed by the body as a whole, but every cell in the body comes from a preceding cell by a process of division and it

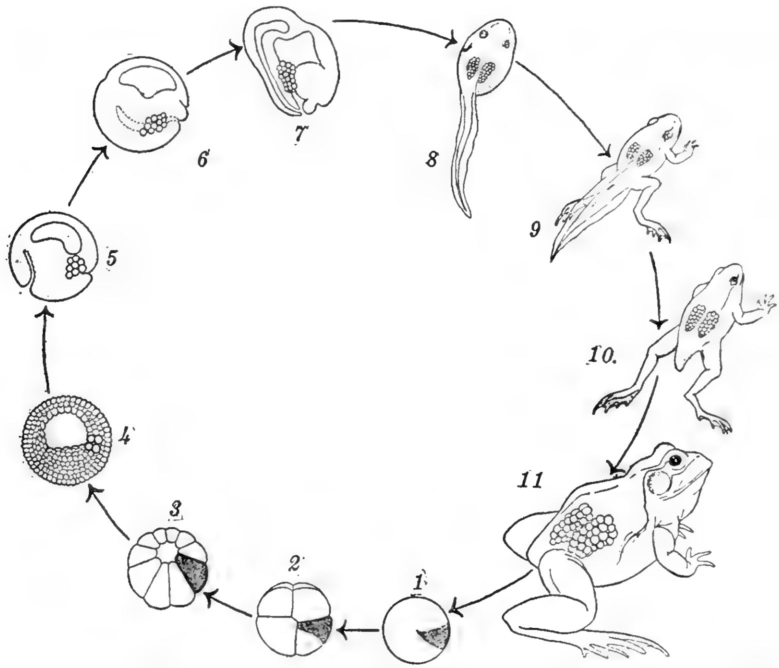

FIG. 3. DIAGRAM OF LIFE CYCLE OF THE FROG SHOWING THE STEPS BY WHICH THE EGG GIVES RISE TO THE BODY OF THE FROG AND TO OTHER EGGS. 1. Fertilized egg; the stippled area is the mesodermal crescent from which the germ cells come. 2. Eight cell stage. 3. Thirty-two cell stage. 4. Blastula showing germ cells in heavy outline. 5–7. Early to late gastrulæ showing germ cells in heavy outlines. 8–9. Early and late tadpoles with germ cells as in preceding figures. 10–11. Metamorphosing and adult frogs containing germ cells which come in direct lineage from the egg shown in 1.

grows, not by contributions of protoplasm from other cells, but by building up its own protoplasm from food substances; and germ cells are formed not by contributions from all parts of the body, but by division of preceding cells, which are derived ultimately from the fertilized egg. Development is not a process which goes forward at one phase and backward at another, but is always and everywhere a progressive movement from the egg to the adult and never one in the reverse direction (Fig. 3). End stages are not added on to previously completed ontogenies for every inherited change, whether of an end stage or of an earlier one must be represented by some change in the germ cell itself.

(*b*) *The "Recapitulation Theory."*—That there is a certain parallelism between the stages of ontogeny and those of phylogeny has long been known, but there has been much difference of opinion, and there is now a widespread misunderstanding as to the significance of this parallelism.

(1) *Truth and Error of Theory.*—The "fundamental biogenetic law" of Haeckel affirms that "ontogeny is a brief recapitulation of phylogeny" or, as some one has picturesquely expressed it, "every organism climbs its own ancestral tree."

Various other hypotheses such as Lankester's "precocious segregation" and Hyatt's "law of acceleration" taught that adult characters tend to appear at earlier and earlier stages in ontogeny, because they are "reflected back upon the germ cells" and thus that what were at one time "end stages" in ontogeny are crowded back into earlier stages, while new end stages are added. The "fundamental biogenetic law" of Haeckel was based entirely upon this idea that in the course of evolution new end stages are added to the ontogeny as it had previously existed. This conception may be represented by the following diagram in which the successive stages in phylogeny and ontogeny are represented in alphabetical series:

Phylogenetic Series	Ontogenetic Series
A	A
B	AB
C	ABC
D	ABCD

Thus the ontogeny of each of these phylogenetic stages was supposed to recapitulate the entire evolutionary series.

And yet among higher forms there are very many adaptations to embryonic and larval life which have no counterpart in lower forms and which indeed could not exist in free-living organisms; such are the embryonic membranes of higher vertebrates, the yolk-sac of fishes, and the modifications of development in these forms and in many of the invertebrates due to the presence of much yolk, the extraordinary modification of the larvæ of many parasites, and the remarkable differences in development which are found in different species of almost every class of animals. Such differences in the ontogenesis of organisms which are otherwise closely alike demonstrate that certain evolutionary changes may occur in embryonic stages without greatly modifying adult stages.

On the other hand, in many cases adult stages have under-

gone much greater changes than have embryonic ones; for example Ascidians are known to belong to the phylum Chordata, *Sacculina* to the Arthropoda, *Myzostomum* to the Annelida, etc., only because in these cases embryonic or larval stages preserve ancestral characters long after adult stages have lost them. In short *evolutionary changes may affect any portion of the life history, and therefore the course of ontogeny is not a sure indication of the course of phylogeny.*

It thus became evident that earlier phylogenetic stages were not always reproduced in the ontogeny and consequently a distinction was made between those ontogenetic stages which repeated the phylogeny and were called by Haeckel "palingenetic" and those which did not and were called "cœnogenetic." Consequently the phylogenetic and ontogenetic series were represented as follows:

Phylogenetic Series	Ontogenetic Series
A	A
B	aB
C	abC
D	abcD

Or since ontogeny is greatly shortened as compared with phylogeny the course of the two might be represented by the diagram on p. 494 (Fig. 4).

(2) *Embryonic Homologies and their Causes.*—Nevertheless, many organisms which differ widely in adult stages reveal a surprising degree of resemblance in embryonic stages and in general embryonic resemblances appear to be more persistent than adult ones. It is certainly no mere accident that practically all animals begin their individual existence as fertilized eggs, that before or during fertilization all eggs produce two polar bodies, that in animals as far apart as flatworms, annelids and mollusks the early cleavages of the egg are fundamentally alike and that where differences exist they have led to the discovery of rudimentary cells in one form corresponding to well-developed cells in another (Fig. 5). It is no accident that the eggs of all chordates have the same type of cytoplasmic localization, that all develop a notochord and nervous system and mesoderm in fundamentally the same way, that all vertebrates whatever have gill slits in embryonic or adult stages, etc. These and thousands of other resemblances of the same sort can be explained only by assuming that they are homologies or inherited likenesses and that forms showing these likenesses are genetically related. But this does not mean that in higher animals addi-

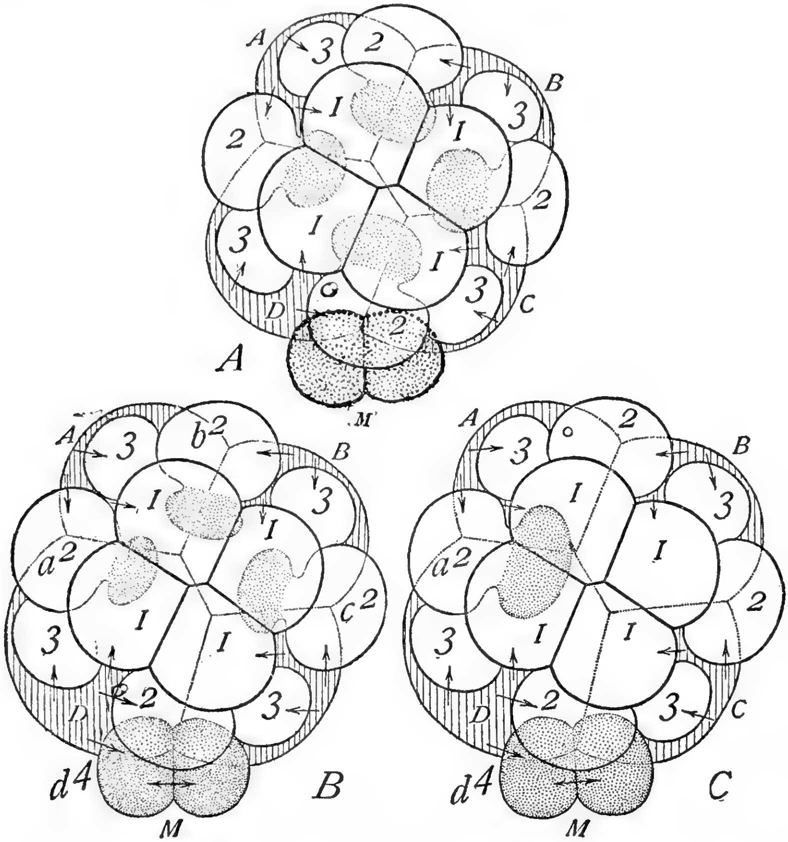

FIG. 4. ANCESTRAL REMINISCENCE IN CLEAVAGE. Showing homologous cells in *A*, a polyclade (*Leproplana*); *B*, a gasteropod (*Crepidula*); *C*, a lamellibranch (*Unio*). (Modified from Wilson.)

tional stages have been added on to those present in lower forms or that adult stages of lower animals have been crowded back into the embryonic life of higher forms as the recapitulation theory assumed. It does not mean that all organisms are alike in early stages of development and that they first become unlike in later stages. We now have direct evidence that several distinct types of animals have distinct types of eggs; thus there are the (1) Cœlenterate, (2) Polyclade-Annelid-Mollusk, (3) Echinoderm, (4) Nematode and (5) Chordate types of egg organization and these do not converge to a common type in the earliest stages of ontogeny (Fig. 6). Echinoderms come from echinoderm eggs, mollusks from mollusk eggs, vertebrates from vertebrate eggs and "the egg of a frog is as different from the egg of a hen as a frog is from a hen."

There are differences of a fundamental order, even in the earliest stages of development, between a vertebrate and an invertebrate, and the early development does not reveal the

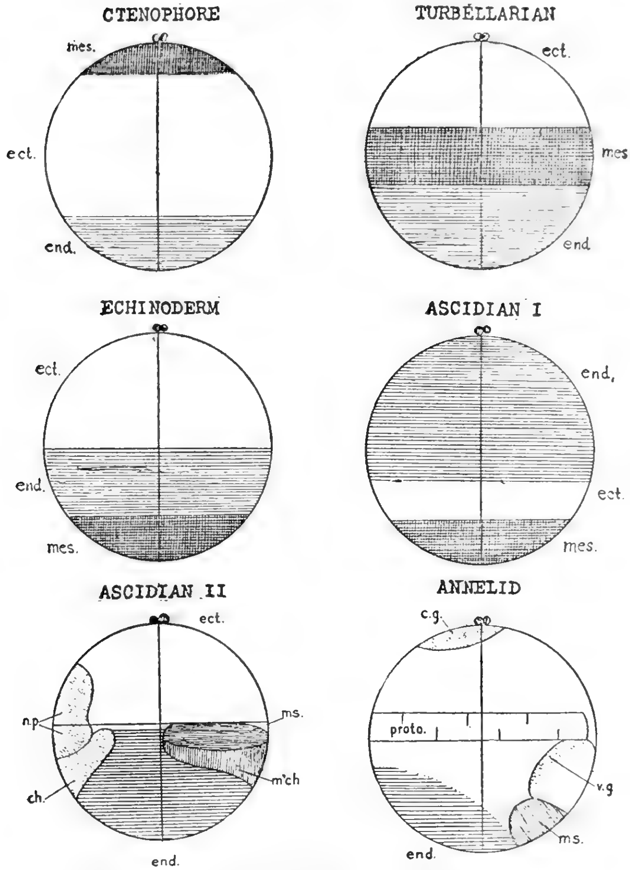

FIG. 5. TYPES OF EGG ORGANIZATION IN DIFFERENT ANIMAL PHYLA. Cross hatched area mesoderm or mesenchyme (*mes*); horizontal lines endoderm (*end*); unshaded area ectoderm (*Ect*). In the first four figures the pattern of localization is that found about the time of the first cleavage; in the last two figures the pattern is that found at a later stage; *n.p.*, neural plate; *ch.*, chorda; *c.g.*, cerebral ganglion; *v.g.*, ventral ganglion; *proto.*, prototroch.

manner in which the one may have been derived from the other. The annelids do not approach the chordates or echinoderms in the earliest stages of development any more closely than in the later stages (Fig. 6). In short there is no convergence toward a common type as one goes back to earlier and earlier stages of

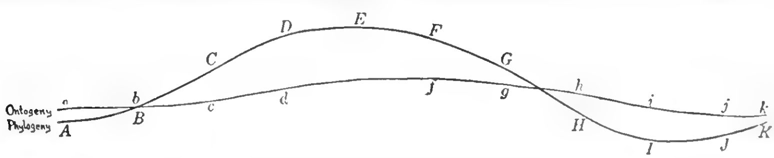

FIG. 6. DIAGRAM OF THE PARALLELISM OF ONTOGENY AND PHYLOGENY, the course of the latter being more roundabout and of the former more direct. Where ontogeny follows phylogeny most closely we have *palingenetic* stages, where it departs from phylogeny the stages are *cænogenetic.*

ontogeny. The recapitulation theory assumes that there is such a convergence in the early stages, but on the other hand the accurate study of the "cell lineage" of eggs and embryos shows that the resemblances and differences between different animals in the earliest stages of development are of the same order of magnitude as those between later stages. Homologies of cleavage must be due to similarities in the protoplasmic organization of the cleavage cells, and the same must be said of homologies of eggs before cleavage begins. Similarities in the protoplasmic substances of eggs and in the pattern of localization must lie at the bottom of all later appearing similarities.

The cause of all embryonic homologies is therefore the same as the cause of adult homologies, viz., inherited likeness in the protoplasm due to community of descent, and it is only because there is increase of specialization as development progresses that the most general resemblances are found in the earliest stages, while more special resemblances occur only in later ones. This alone explains the fact that embryonic resemblances are on the whole more persistent than those of the adult.

(3) *Resemblances in Functions and Processes more General than in Structures.*—The stages of phylogeny are not exactly repeated in the ontogeny because all conditions both intrinsic and extrinsic are not the same, but the principles of *heredity* and *variation,* of *differentiation* and *development,* are everywhere the same in all plants and animals and men, and these principles of ontogeny are at the same time the principles of phylogeny. Ontogeny recapitulates phylogeny not in all its stages and forms, but in its *factors* and *principles.* All the fundamental principles of evolution from ameba to man are involved in the development of a single link in this long chain.

(*c*) *Inverted View of Phylogeny.*—A false trend was given also to all theories of evolution before Weismann by failing to give sufficient attention to the fact that the germ cells are the only bond between species as well as between generations. In older theories of evolution the great fact of ontogeny was neglected and it was generally assumed that one mature form underwent modification by which it was transformed into another. Adult stages of different types were compared and it was shown how one could be derived from the other by turning it upside down, by closing up the old mouth and opening a new one somewhere else, and by making other equally radical changes in a fully developed organism (Fig. 7). Ontogeny was temporarily forgotten and the fact was overlooked that mature organisms do not produce mature organisms, but that each generation arises from germ cells which alone are continuous from generation to generation.

Until recently, evolution was regarded almost entirely from the standpoint of the developed organism. The great problem of evolution was supposed to be the method by which one type of developed animal or plant gave rise to another type. Mature organisms are known to undergo changes in response to environment or to conditions of life and these changes were regarded as evolutionary ones. Thus Lamarck supposed that the numerous modifications which adult plants and animals undergo in response to conditions of climate, food, use or disuse, etc., are real evolutionary changes which convert one type into another, and even down to the present time there are many naturalists who hold the same view. Indeed many scientists who would refuse to be classified as Lamarckians, because of some minor disagreement with the views of the great French naturalist as to the cause of evolutionary changes or their method of inheritance, nevertheless hold against all opposition the *main tenet of Lamarckism, viz., that evolutionary changes are first wrought in mature organisms*. The classical illustrations of this, which were cited by Lamarck, are familiar to every one, such as the elongation of the neck and forelegs of the giraffe by attempting to reach higher leaves on trees, and the loss of limbs in snakes because of disuse in the narrow quarters in which they live. Many somewhat similar illustrations of this view that evolutionary changes first appear in adult organisms were cited by Darwin, such as the reduction or loss of wings in certain birds or the loss of eyes in cave animals, owing to disuse. More recent literature is filled with such instances; I need only refer to the opinions of many paleontologists, whose studies must of necessity be confined largely to mature organisms, that evolutionary changes take place in these

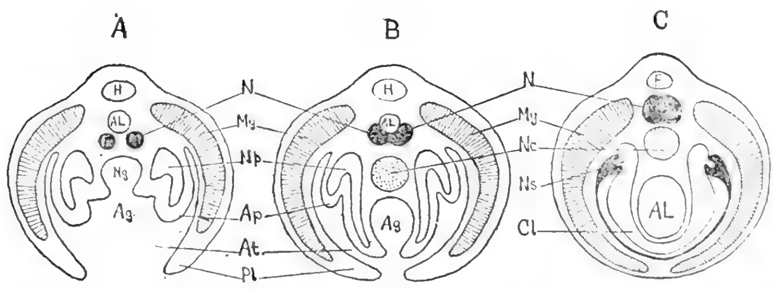

FIG. 7. DIAGRAMS OF THE SUPPOSED ORIGIN OF VERTEBRATES FROM TRILOBITE-LIKE ANCESTORS, ACCORDING TO GASKELL. Cross sections of the body of (*A*) Trilobite, (*B*) Intermediate form, (*C*) Vertebrate. The alimentary canal (*AL*) of the Trilobite becomes the neural canal (*N*) of the vertebrate, while the alimentary canal of the latter is derived from a groove on the ventral surface of the Trilobite's body (*Ag*) which is folded in to form a tube. The notochord (*Nc*) is likewise derived from a ventral groove (*Ng*) of the Trilobite's body. *H*, heart; *My*, myotome; *Np*, nephrocoel; *Ap*, appendages; *At*, atrial chamber; *Pl*, pleuron; *F*, fat body; *Cl*, coelom.

organisms by the addition of new "end stages" to those previously present; or to the views of the older anatomists that inverse symmetry, or "situs transversus," is caused by the transposition of developed organs from one side of the body to the other; or to the various theories as to the origin of vertebrates from actinians, nemerteans, annelids, arachnids or other invertebrates, by the inversion of the developed bodies of the latter and the transposition and transformation of certain organs (Fig. 7). Indeed all persons are by nature Lamarckians, and for this very reason that attention is focused upon adult organisms which are seen and known of all men rather than upon the germ cells which are usually unseen and unknown.

In all of these cases modifications of adult organisms were supposed to have brought about the changes from one species to another or from one phylum to another. The great problems of evolution were (1) to determine how these adult changes were produced and (2) to show how they were carried over or "transmitted" from one generation to the next. With regard to the last named problem it was evident that these adult changes, if they were to be handed on must be impressed in some way upon the germ cells, since the germ cells form the only living connection between successive generations. Consequently various hypotheses arose, such as were described in the previous section, to show how adult characters might be "reflected" back upon the earlier stages of ontogeny or even upon the germ cells themselves.

(*d*) *Inverted Views of Heredity or the Inheritance of Acquired Characters.*—This is what was originally meant by the phrase "inheritance of acquired characters," namely that changes in adult structures and functions are in some way impressed upon the germ cells so that these identical changes are thereafter inherited. Darwin was the first to suggest a possible mechanism for such inheritance of adult characters in his "Provisional Hypothesis of Pangenesis." He assumed that every portion, perhaps every cell, of the developed organism gave off minute living units or "gemmules" and that these gemmules accumulated in the germ cells and in the course of the development of these cells the gemmules became active and gave rise to parts or cells similar to those from which they originally came. Incredibly complex as such a process must be in normal ontogeny, it became still more complex when the attempt was made to explain the "inheritance of acquired characters," for since *ex hypothese* such characters can be acquired and reappear in offspring at any period in ontogeny it was necessary to assume that these gemmules were given off from all the cells at

every period of life. Apart from positive disproof of the hypothesis which was quickly furnished by Galton, it must have broken down from its own weight of incredible assumptions and additional hypotheses.

Since Darwin's time many attempts have been made to devise a more acceptable hypothesis to explain the mechanism of the "inheritance of acquired characters." Many of these are mere modifications of Darwin's hypothesis of pangenesis; others involve the transmission from the body to the germ cells of other, and usually more mysterious, things than gemmules. Among these are supposed "impressions," either nervous, psychic, or mnemonic, but in every instance these speculations follow Darwin's hypothesis in supposing that something proceeds from every part of the adult organism to the germ cells and so modifies those cells that in the course of their development they reproduce the very stages and changes which the adult organism first manifested. They are built on the erroneous idea that the body makes the germ cells; they represent the inverted view of development.

These hypotheses are not only pure assumptions, but in the main they have been invented to explain phenomena which are themselves pure assumptions. Thirty-five years ago Weismann boldly challenged the generally accepted doctrine that "acquired characters" *are* inherited, and from that day to this probably not a single case of such inheritance has been demonstrated, while most of the supposed cases of such inheritance could be better interpreted in some other way. Those who still believe in such inheritance are compelled to admit that it occurs very rarely and exceptionally if at all.

The older ideas of inheritance represented developed characters as being transmitted from one generation to the next; a son was said to have inherited his father's nose or his mother's eyes as if these developed characters were transmitted unchanged. But such a view entirely overlooked the facts of development; characters are never transmitted but only the germinal elements or "factors" of characters and characters develop from these only under the influence of environment, so that every developed character is due to both inheritance and environment. The distinction between inherited and acquired characters is therefore not a logical one, for every developed character is both inherited and acquired. In its original meaning, therefore, the term "inheritance of acquired characters" may be dismissed as not only illogical, but as also impossible in sexual reproduction.

Unfortunately this expression is now used not only in its

original sense but also with a very different meaning, viz., the modification of the germplasm through environmental influences, or more briefly the "inheritance of germinal modifications." Indeed the latter is all that is usually meant when the former expression is used, for few if any persons would now maintain that developed characters can enter into or impress themselves upon the germ cells so as to be born again in the next generation. On the other hand it is quite possible that environmental influences may act upon the germ cells so as to alter

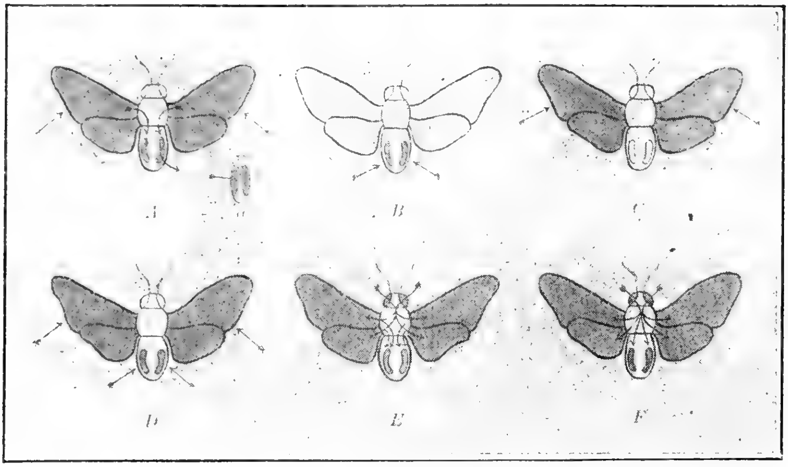

FIG. 8. DIAGRAM TO SHOW THE VARIOUS WAYS IN WHICH ENVIRONMENT MIGHT INFLUENCE THE GERM CELLS. *A*. Environment modifies the body and the latter, the germ cells so as to produce identical modifications in the next generation (*a*) ; this is "inheritance of acquired characters." *B*. Environment modifies the germ cells but not the body. *C*. Environment modifies the body but not the germ cells. *D*. Environment acts independently upon both body and germ cells. *E*. Environment acts through nervous system on different parts of the body which parts in turn modify the germ cells. *F*. Environment acts through nervous system upon various parts of the body and at the same time upon the germ cells.

their hereditary constitution. Whether this possibility is ever realized, whether extrinsic conditions may ever modify the germplasm so as to produce permanent changes in heredity, is the central problem of evolution.

It is conceivable that the environment may modify the germ cells in one or more of the methods shown in the accompanying diagram (Fig. 8). In A the environment is supposed to modify the body or soma, which in turn modifies the germ cells so that they produce a body modified like the parental one; this is typical inheritance of an acquired character, and it probably never takes place. In B the environment is shown acting directly upon the germ cells but not upon the body, and in C upon the body but not upon the germ cells, while in D the environment acts independently upon body and germ cells. Probably all of

the conditions shown in B, C and D actually exist but it should be noted that when germ cells are modified by environment these modifications are not identical with those of the body nor do they develop into such modified bodies; in short in these three cases there is no inheritance of acquired characters. Finally in E and F are shown two possible ways in which environment may influence the germ cells through the body; in E the environment is supposed to act through the nervous system on various parts of the body, which parts in turn act upon the germ cells; while in F there is parallel action, through the nervous system, upon various parts of the body and also upon the germ cells. There is no satisfactory evidence either for or against the conditions shown in E and F and it is possible that they as well as B, C and D may represent actual conditions. Only against the condition shown in A, that is against the inheritance of acquired characters in the original sense, is the evidence conclusive.

While it is undoubtedly true that the egg produces the hen and other eggs, and that the hen, that is the body or soma, does not *produce* the egg, it is equally true that the body of the hen, which is the environment of the ovarian egg, may *modify* the egg just as the external environment may modify the organism as a whole. But experience shows that such modifications are usually not inherited, they come and go with changing environment, they represent indeed the reactions of a relatively stable organism to an unstable environment. Least of all do these modifications of the germ or of the developed organism *resemble* the changes of the internal or external environment which called them forth; a hen with an artificially modified ovary or oviduct or thyroid gland may possibly produce a modified kind of egg, but there is no more reason for supposing that the chick into which this egg develops will show the same modification of ovary, oviduct or thyroid gland than there is for supposing that a cold climate will produce a race of cold-blooded animals or a vegetable diet a species of vegetable-like animals,—and this because the responses of a germ or of a developed organism to its environment in no way *resemble* that environment. The darkness of caves does not *produce* the blindness of the animals that live in them, much less does it modify their germ cells in such a particular way that they in turn produce blind animals; it is possible, though it has never been proven, that environmental changes may cause changes in the germplasm, but it is extremely improbable that these changes are of such a sort that they will lead, after a long process of development, to the production of just such adult characters as are adapted to the

environment which caused the germinal change. Such a view involves on the part of the germplasm such a foreknowledge of future events and contingencies as could not logically be ascribed to deity itself, and which is impossible of scientific formulation or explanation. If environment ever modifies germplasm it is safe to say that these modifications neither *resemble* the environment nor, except in rare circumstances and by chance, are they *adapted* to develop into organisms which will be fitted to that environment.

Probably germ cells may be modified by the soma within which they develop as well as by outside conditions, by internal and also external environment, but there is no justification in this fact for the claim which is often made that "adult characters are reflected" from the soma to the egg or that the environmental modifications of the parents produce identical modifications in offspring,—no evidence for the opinion that because "the parents have eaten sour grapes the children's teeth are set on edge." Further consideration of the effects of external and internal environment on germplasm will be considered in a later section.

In short, development is progressive and not retrogressive, the germ cells are descended from germ cells of the preceding generation and not from the somatic or body cells by which they are surrounded, and while these somatic cells may influence or modify the germ cells by chemical products such as enzymes and hormones and possibly also in other ways, these modifications are usually temporary and are not inherited, and, contrary to the old doctrine of "inheritance of acquired characters," they do not resemble the stimulus which called them forth nor forecast the needs of the future organism into which they will develop. Even when inherited modifications are produced in germs cells by changes in the external or internal environment these modifications may not resemble those produced in somatic cells, and in no instance is there any evidence that modifications of somatic cells are transmitted from these to the germ cells.

The Lamarckian philosophy, under whatever name it appears, is based upon a belief in vitalism or preformation; either the germ foreknows the future needs of the organism by some mysterious vitalistic power, or it is the miniature of the adult and reacts to environment in the same way as the adult does. Neither of these suppositions accords with known facts, and both are contradictory to the spirit of science, for the one makes effects determine causes rather than the reverse, while the other affirms that causes and results are identical. It will always be one of the marvels of the history of science that whole genera-

tions of more or less thoughtful men, who were more or less acquainted with the phenomena of organic development could have wandered about so long in such a stupid maze.

(*e*) *The Inverted View of Selection.*—The inverted view of development lurks in many theories where it would least be expected; not merely in the transmutation of one developed species into another, and in the inheritance of acquired characters, but also to a certain extent in selection theories, for in both artificial and natural selection it is usually assumed that evolution takes place by the elimination of developed organisms and that individuals which survive "transmit their characters" to their offspring or "produce germ cells like those from which they came." Of course no adult characters are "transmitted" to offspring and no developed organism "produces" germ cells, but apart from this criticism of the terms used, which may or may not be associated with the inverted view of development, all recent studies of heredity show that not all the different germ cells of an individual are genetically alike except when that individual is absolutely homozygous, a condition which rarely occurs among sexually reproduced organisms, so that the adult organism selected may or may not contain germ cells which are like those from which it came. Thus if the hereditary constitution of the maternal germ cell is represented by *ABC* and that of the paternal cell by *abc*, the offspring would give rise to no less than eight different types of germ cells, only one of which would be like the maternal and one like the paternal cell as is shown in the accompanying diagram:

$$\left.\begin{matrix}\mathrm{ABC}\\ \mathrm{a\ b\ c}\end{matrix}\right\} = \begin{matrix}\mathrm{ABC,\ aBC,\ AbC,\ ABc}\\ \mathrm{abc,\ Abc,\ aBc,\ abC}\end{matrix}$$

Pearl has shown that some of the conflicting results as to the influence of selection in evolution may be attributed to this fact. Consequently the selection of developed organisms in the hope of thereby isolating particular germinal types is a blind and imperfect process, though it is the only possible method of procedure, since the hereditary constitution of germ cells can not be recognized directly. Nevertheless it is necessary here also to avoid the inverted view of development involved in the assumption that a certain type of adult organism "produces" germ cells of the same type.

Furthermore the opinion that the principal activity of selection is in the elimination of developed organisms directly reverses the known facts in the case. Elimination is most severe in germ cells and embryonic stages. Where one adult is eliminated tens of embryos and thousands of germ cells are elimi-

nated. These matters will be treated more fully in the section on selection.

(*f*) *The Inverted View of Adaptation.*—Akin to these inverted views of development which put the adult before the germ, the effect before the cause, the end before the beginning, are those views of adaptation which represent needs, advantages and ends as causes of organic fitness. According to these views there is present in organisms a guiding or perfecting principle, an "entelechy," "élan vital" or other unknown cause, which leads to definite and purposive results, just as human intelligence does. It is said by certain philosophical biologists that evolution and adaptation should be looked upon from the standpoint of man, their highest product, rather than from the standpoint of the simplest organisms; evolution should be explained as the result of intelligence and purpose rather than attempt to explain intelligence and purpose as the effects of evolution. In short, according to this view, fitness, purpose and intelligence are causes rather than effects of evolution and adaptation.

But there is no sufficient evidence that even in human intelligence and purpose the usual rule of cause and effect is reversed, and there are many evidences that this is not the case. In human behavior the remembered results of many previous experiences enter as causes into future actions which may thus be directed to desired ends; human intelligence and purpose have thus been built up out of sensations, reactions and remembered experiences. Probably a similar explanation may be given of the adaptive behavior of many organisms, for if results of previous experience may be conserved to any extent in protoplasm then subsequent reactions may be explained as the result of past experience, the elimination of useless reactions and the persistence of useful ones. And in similar manner all kinds of adaptations may be explained as the result of the Darwinian principle of the elimination of the unfit and the survival of the fit. There is therefore no necessity for assuming that needs, advantages and ends serve as causes of adaptation. This inverted view of cause and effect is as unnecessary as is the inverted view of development.

On the other hand certain philosophers and biologists maintain that the responses of organisms to stimuli are always adaptive; Bergson in particular has supported this hypothesis. That there is considerable evidence in favor of such a view may seem to be proven by many well-known instances of regulation and regeneration, by many protective and preservative reactions which one finds in organisms; just as the soma usually responds to stimuli in adaptive ways, so it is maintained the germplasm

also responds adaptively. However, Darwin and many others have shown conclusively that somatic responses are not always adaptive and that those which are such vary greatly in degree of perfection. That every change in the germplasm is an adaptive change to the environmental stimulus which called it forth is a thesis impossible to maintain, as is demonstrated by all recent work on mutations. Most of these mutations are positively injurious and do not in any degree make the organism better adapted to the conditions in which they arose. Furthermore it should be noted that the assumption that germplasm may respond adaptively to external stimuli really signifies that the germplasm responds in such a way that the developed organism to which it gives rise is better adapted to the environment and not that the germplasm itself is better adapted; therefore if such beneficial responses really occurred they would be beneficial only in an anticipatory way and they would be beneficial to the germplasm only secondarily and very indirectly. This hypothesis also is based upon the inverted view of development, namely, that developed organisms create and control the germplasm rather than the reverse. The fact is that there is no evidence that either germplasm or somatoplasm always responds to the environment in a directly beneficial way. The usual beneficial character of responses must be explained in some other manner.

In conclusion, all hypotheses which assume that evolutionary changes first occur in developed organisms and are then "impressed" in some manner upon the germ cells neglect entirely the well-known fact that development is not a reversible process; a man can not enter a second time into his mother's womb and be born again and a developed organism can not again become an egg. Consequently all such hypotheses not only put the cart before the horse, but they put the end of the journey before its beginning. It is now plainly apparent to those who have considered the problem of evolution most seriously that evolution must take place by modifications of germ cells or of germplasm rather than of adult organisms. Consequently all the older theories of evolution and many of the newer ones which are based upon that ancient and erroneous idea that the hen produces the egg and not the egg the hen may be dismissed without further consideration here. They represent an untenable and inverted view of organic development, for while it is absolutely certain that the fertilized egg produces the developed organism it is equally certain that the latter does not produce the former, but that every germ cell comes in direct lineage from the germ cells of the preceding generation.

(*To be continued*)

OUR UNIVERSE OF STARS

By Professor ERIC DOOLITTLE

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THE observer who stands out under the heavens on any clear, moonless night will see the light of far distant suns shining upon him in whatever direction he may turn. If he is fortunate enough to be so far away from artificial lights, and in so clear an atmosphere that the background of the sky is nearly black, the stars that surround him seem almost innumerable. He knows that all of these are great suns, many of them far hotter and brighter than our own sun, and that the nearest is so far away that its light has spent several years in coming to him, although light travels with the enormous speed of 186,330 miles a second. It can not be long before there comes to him some realization of the immensity of the great cloud of suns in which we are immersed.

Most striking and interesting of all to the naked eye is the Milky Way, that

> Broad and ample road whose dust is gold,

so very bright and narrow in Cassiopeia, but much wider in Cygnus, where begins that most remarkable feature known as the Great Bifurcation. Here the Milky Way branches into two parts. The western branch is the brighter until Aquila is reached, where it diverges still farther to the west, and comes almost completely to an end in Ophiuchus, to begin again in Scorpius. The eastern branch meanwhile grows narrower and remains bright, until it passes below the ground in the south. Between Aquila and the horizon is the most irregular region of the entire structure. Here suns are heaped together into great clouds which alternate with faint, or almost absolutely vacant, spaces.

When a great telescope is turned in any direction, the field of view is filled with stars, which become more densely packed together as the Milky Way is approached; indeed there are parts of this which can not be resolved into separate stars, even with the most powerful optical aid. And when a delicate photographic plate is exposed for many hours to any part of the heavens, the images of continually fainter and fainter stars appear upon it, until a record is secured of objects far too faint to be seen in any telescope. There are also revealed innumer-

able additional star-clouds and star-clusters, double and variable stars, and, in short, all of the objects the study of which makes up modern sidereal astronomy.

Evidently, the star cloud which surrounds us is of almost infinite complexity. It is no wonder that Sir William Herschel, its first explorer, became wholly absorbed in his work, and that his devoted sister, Caroline, sat, night after night, recording his observations until her feet were frozen to the ground. Not only did Herschel describe and catalogue for the first time thousands of double stars, nebulas, and other objects, but he sought to get some approximation to the form of the cloud of suns of which we are a part. This he did by counting vast numbers of stars seen in different directions and assuming that the relative distances of the stars could be found from their comparative brightness; that the fainter stars, on the whole, appeared faint only on account of their great distances from us. Thus he reached the conclusion that our universe has roughly the form of a grindstone, the greatest dimension lying in the direction of the Milky Way, and our sun being near the center.

But unfortunately, this assumption of Herschel with regard to the fainter stars can only very roughly be said to be true. We now know that the faint and bright stars are inextricably mixed in our star cloud; some of the nearest stars of the heavens are very faint and some of the brightest are so far away that their distances can not be directly measured. In addition to this, the surprising fact appears that the distribution of the stars depends to a large extent upon their comparative development. Those but little advanced from a nebulous stage congregate strongly in the direction of the Milky Way; those which have proceeded farther in their development surround us in a much less flattened cloud.

Taken as a whole, we now know that our Milky Way cloud of stars, though inconceivably vast, is far from being of infinite extent. It is also of a much more complex structure than described by Herschel. The stars of our visible universe are arranged in a flattened, lens-shaped form, the least distance through which is perhaps 2,000 light years, and of which the greatest diameter, extending in the direction of the Milky Way, is possibly four times as great. To a distance of about 300 light years in every direction, the distribution of the stars is nearly uniform. Beyond this the numbers rapidly fall off, until at a distance of 1,000 light years in the direction of the Poles of the Milky Way, the density is diminished to perhaps one fifth of that at the center. Around the edge of the great disc are the irregular clouds of the Milky Way, the inner edge of the nearest of which is perhaps 4,000 light years from us. Some astrono-

mers believe that there is an almost vacant space between the stars of our inner, flattened cloud and the complicated structure which surrounds it.

The individual suns which make up this complex cloud were, until very recently, believed to be moving indifferently in every direction, and in regard to a majority of them this is still believed to be true. But the surprising discovery was recently made that many of the stars belong to two great streams moving in both directions along a line which lies in the place of the Milky Way. There are thus two streams, the stars of which move in exactly opposite directions; one stream is not in front of the other, but they inter-penetrate one another in all parts of the heavens.

We can not yet definitely account for this great streaming of the stars. Dr. H. H. Turner has suggested that it may be explained by supposing that the stars of our universe move in very large but narrow orbits about the gravitational center of our cloud and that we view them going and returning from that center, from which our own sun is at a considerable distance. The strongest objection to this theory is that it requires too strong a congestion of stars near the center. While it is possible to suppose that one of the dense patches of stars in the Milky Way is the actually congested center of our stellar system, until much more data have been accumulated it will not be possible to come to any decision in regard to the theory.

All that has been said thus far is based on a study of the bright objects of our universe, those which can be seen in the telescope or which appear after a long exposure on a delicate photographic plate. But is all, or even a large proportion, of the matter in our universe gathered into self-luminous bodies? May there not be vast quantities which, like the meteorites and shooting stars which continually fall on our earth, are dark and so invisible to us? And may not the whole cloud be filled with a cosmic dust whose mass may far exceed the combined masses of all the brighter stars? If so, the gravitational pull of this diffused matter becomes of dominant importance in any inquiry into the future development of our system.

Fortunately, if the space within our star cloud is filled with finely divided matter, not only will the light from far distant suns be rendered fainter, but it will also be reddened in color. The reddening effect of a fine dust was very noticeable 36 years ago, when all of the air about the earth was filled with dust from an eruption of the great volcano, Krakatoa. This was a time of intensely red sunrises and sunsets which persisted for more than a year until, after the slow settling down of the dust particles, the air was again comparatively clean.

Thus, if finely divided matter exists in inter-stellar space, the more distant stars will be distinctly reddened. If a large number of stars known, or believed to be, very distant are arranged in a series according to their color, there will be a larger proportion of red stars than there are among those in the vicinity of our sun. Moreover, very blue stars will not be seen.

Studies based on this change of color have been carefully made by several observers, but the observations are very difficult and the results are discordant; the largest of the modern results is nearly three times the smallest. An average of the three best determinations indicated, however, that there is the equivalent of about 50,000 hydrogen molecules in each cubic centimeter of space. This is, of course, very far beyond the most perfect vacuum which we can attain artificially, and it would probably have no appreciable effect on the motion of the planets, but in a study of the development of our universe its effect becomes very important. For the total mass of this material would be no less than 150,000 times the estimated mass of all the stars in any large region of space.

An apparently more reasonable conclusion was reached three years ago by Dr. Harlow Shapley, of the Mount Wilson Solar Observatory, from a study of the bright cluster of stars in Hercules, and several other spherical clusters. This is the brightest star cluster visible to northern observers; it is almost overhead in the early evenings of July, and indeed is in excellent position for observation throughout the summer. In this wonderful aggregation of suns, more than 50,000 separate stars have been counted, down to the twenty-first magnitude, and the whole number must be vastly greater than this. The Hercules cluster is very remote from us; its distance is so great that the light of its stars occupies some 30,000 years in coming to us. Thus, it is wholly beyond the borders of our Milky Way universe.

Now when the stars of this very distant cluster are examined in regard to their color it is found that their distribution is almost indistinguishable from that of the stars which are near our sun. So little is this alteration that it is found to correspond to an extinction of but one per cent. of the intensity of a ray of light in travelling through space for 3,000 years.

From thirteen clusters examined in this way, Dr. Shapley has obtained practically identical results. As these objects lie in all different directions from us, the transparency of space is thus tested in these many directions. In each of them the amount of cosmic dust is found to be so small as to be almost negligible.

Inter-stellar space is, so far as cosmic dust goes, very clean. But there may be dark stars and dark nebulas in our star cloud

whose only effect is to cut off the light of whatever is beyond them. Of this nature, probably, are some of the dark spaces in the Milky Way, recently photographed and discussed by Dr. E. E. Barnard. No one can doubt that in some of these beautiful photographs we see the distant clouds of stars partially hidden by dark matter in front of them. But this opaque matter is very local. In general, there is no evidence of any dark material between us and the distant stars. We are therefore justified in estimating its total amount as but small compared with the whole mass of the stars.

If we therefore suppose that there is not an excessive amount of dark matter in our universe, we may proceed to inquire how the form of our star cloud will change under the action of the bright bodies which compose it. And it may be remarked that even if we assume the mass of dark matter as equal to, or even greater, than that of matter visible to us, the general character of our conclusions will not be altered.

But at the very outset we must decide between two wholly different modes of investigation. Until very recently it was believed that the stars can be compared to the molecules of a gas and that the laws applied in the theory of gases can be equally applied to our cloud of stars. These laws depend very largely upon the incessant collision and rebound of the gaseous molecules, by which the energy of motion is communicated from one to the other. Do the stars pass close to one another frequently enough (for actual collision is not necessary here), to make the kinetic theory of gases applicable, or are their close approaches relatively so infrequent that the gravitational pull of all of the stars of the cloud is all that need be considered?

Some light is thrown on this question by the quite recent discovery of several clusters of stars, ploughing directly through the cloud of stars which surrounds us. Perhaps the best known of these, and the one which has been most fully investigated, is the moving cluster in Taurus. This is a group of 41 bright stars, scattered over the whole western half of the constellation, though mostly concentrated about the Hyades, a study of whose motions shows that they are moving together through our star cloud. They are all moving in perfectly parallel lines with a speed of 28 miles a second. They, in fact, make up a globular star cluster, about 35 light years in diameter; this passed nearest us about 800,000 years ago; when viewed from the earth at this time the individual stars seemed even more scattered than at present. In 65,000,000 years the group will appear as a little round cluster of faint stars, five eighths the diameter of the full moon.

As we know the distance away of this cluster, it is easy to

find the absolute brightness of each of its stars. It is interesting to note that they are all far more luminous than our sun, the brightest ones exceeding the brightness of our sun by nearly 100 times. In the neighborhood of our sun we have nothing to compare with this brilliant assemblage of stars. Perhaps there are many fainter stars within the borders of the cluster, and belonging to it, but the motions of the fainter stars have not yet been so studied as to enable us to decide this point.

A second, very celebrated, cluster is known as the Ursa Major system because all of the stars of the Great Dipper are known to belong to it except the two extreme ones. It also includes the brightest star of the delicate little constellation of the Northern Crown and the very brilliant Dog Star, Sirius. This is a very flattened, disc-shaped cluster with an extreme diameter of about 110 light years; its thickness is only 8 light years. This cluster is moving somewhat more slowly than the cluster in Taurus, its speed being but 18 miles a second. All of its stars are far brighter than the sun.

Several other moving clusters are known. For our purposes, the striking fact to be noticed in connection with them is that though each one moves through the star cloud so that innumerable stars, distinct from the cluster, must be enveloped by it and afterward left behind as the swarm moves on, yet the stars of the cluster continue to move with an unchanged velocity and in parallel lines. It appears that even in these exceptional cases the chance near approach of two stars is a very unusual occurrence.

It is true that M. C. V. L. Charlier and other astronomers, who believe that the effects of near approaches should be taken into account, suppose that the stars remaining in the cluster are an insignificant remnant of a far greater swarm, most of whose members have been deflected by the stars of our cloud, and so driven away. But if this is so, it seems improbable that those which remain should have absolutely parallel and common motions. It seems more reasonable to suppose that from an original great swarm there should ensue all imaginable deflections from parallelism, from the slightest to those so great that the corresponding members have been driven out of the system altogether.

When, therefore, we consider the phenomena of moving clusters, and think too of the great distances which separate the stars, the evidence seems conclusive that the effects of occasional collisions may be altogether neglected. We need only consider the effects of the general gravitational attraction of the whole cloud of stars, and the kinetic theory of gases may be discarded in this connection.

But even with this restriction the problem is a very difficult one, calling for a development of the science of dynamics beyond any as yet available. However, certain general conclusions can be reached, even if the details can not be as yet filled in.

Whether we consider the kinetic theory of gases as applicable, or not, it appears that our universe is far from a form in which equilibrium can exist. It is in a state of rapid collapse. It may, under the gravitational pull of each of its suns, reach a condition of approximate equilibrium in 1,000,000,000 years. For an almost complete equilibrium, a duration 1,000 times as long is required. And under the kinetic theory, the times are about 100,000 times as great as these. At the expiration of these inconceivably great times, our cloud will probably be found of an approximately spherical form.

An interesting question here arises as to whether each star of our cloud will not have gone through its life long before these changes shall be consummated. Whether each of the bright stars will not have become cold and dark, ages upon ages before that remote time, and whether, if there are then any bright bodies in the universe, they will not be new stars, different from those we see now. For, according to the classic theory of Helmholtz, the life of a sun is a comparatively short one. This theory assumes that all of the heat radiated by a sun into space is caused by the slow contraction of the radiating body; every portion of the mass in thus falling toward the center loses its energy of position, which is transformed into heat energy and radiated away. It is a very simple matter to compute the past and future duration of our sun, for example, supposing that all of its heat is due to this source and that its radiation has remained sensibly constant. It is found that it could not have given off heat at its present rate for more than about 30,000,000 years, and that in 7,000,000 years from now it will have shrunk to one half its present radius; its increasing density will then probably cause its shrinking to be very much slower, and its heat and light will also begin to rapidly decrease.

But from geological considerations a much longer time is wanted. From a physical discussion alone, Sir George Darwin considered that "500 to 1,000 millions of years may have elapsed since the birth of the moon," and Dr. John Perry states that "if the paleontologists have good reasons for demanding greater times, I see nothing from the physicist's point of view which denies them four times the greatest of these estimates." And the paleontologists ask for a very long time to reasonably account for the grand upward development of life upon our earth. For many years it has been indeed evident that the contraction theory of Helmholtz is inadequate. Not that the con-

traction of the sun is not a true source of heat, and this cause must be ever in operation, but a greater source of energy must be looked for. And this, it is now thought, may be found in the atom.

During the past two decades, modern physicists have gotten very far away from the "small, round, smooth atoms" of Democritus. We know now that the atom is a very complex thing. With so-called radio-active substances it may be broken up, with the liberation of an immense amount of energy, the newer elements which result from the process having lower atomic weights than the original substance. Whether an appreciable amount of the heat and other energy emitted by the sun is of this sub-atomic origin, we do not know, but it seems not unreasonable to suppose that it is. For we can not even approximate to conditions as they must be found within the solar globe. It is true that the average temperature of the outside surface of the sun probably does not far exceed 12,000° Fahrenheit, but how very much hotter it is in the interior we have no means of knowing. The pressures, too, within the ball of the sun, are enormous. A very simple computation shows that at the depth of only 1,000 miles below the surface the pressure is nearly 6,000,000 tons on each square foot, an amount, of course, which we are wholly unable even to approach in our laboratories. It seems very probable that when subjected to these inconceivably great temperatures and pressures, atoms may be broken up, and a part, at least, of their sub-atomic energy may be liberated. And it is only necessary to suppose that a part of the energy of the atom is in this way radiated into space in order that the life of a sun, or star, may be almost indefinitely prolonged.

A rough image of the form which our stellar universe will take in the very remote ages of the future is furnished by those beautiful objects, the spherical, or globular, clusters of stars. The remarkable work of Shapley has shown that these are on the borders or wholly beyond the limits of our star cloud. They are isolated in space, and from probably irregular clouds have slowly taken the spherical form under the mutual pull of all of their stars. They are much smaller than our universe; the distance through them is measured in hundreds, instead of in tens of thousands of light years; they have therefore gone through their development much more rapidly. But it is very probable that our own far greater system will take approximately this same form, after a time so long that all times hitherto considered in astronomy shrink almost to nothing in comparison.

INDIVIDUALITY IN RESEARCH

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THE men of no other country have exhibited so great a measure of individuality in research as those of England. In the highest degree they have manifested the self-reliant strength of natural genius. Among them scientific endeavor has not been organized; and for the most part investigations have been carried out by single workers in isolation. British science has always refrained from congregating in distinct schools and institutions; it has never been localized in definite centers. No compact body of pupils there develops the work and ideas of any master. Thinkers proceed singly and individually with their self-appointed tasks laboring in close touch with nature and according to their particular inclinations.

These peculiarities of British science have always been in evidence from the earliest times through the central achievements of Newton and down to our own day. In illustration of the way of work of a scientist in England let us consider the contributions of Faraday, through whose labors the theory of electricity has been revolutionized. Guided by his own experimental researches, which resulted in the knowledge of many new facts and opened up problems of far-reaching importance, he developed his own mental construct or individual way of representing the phenomena to his thought which was so far different from that employed by others that only a few in a generation were able to follow him in the course of his reasoning. He pictured space in the neighborhood of an electric charge as filled with lines of electric force and through these lines found a means of penetrating to a deeper understanding of electric phenomena than any of his predecessors or contemporaries. By aid of an active imagination he was able to ascertain the nature of the interactions among electric charges, representing these to himself by means of geometric relations among his innumerable curved lines of force.

For a time it seemed to most interested persons that his processes were too loose to permit of confidence in his conclusions; though all admitted that they had led him into the most interesting and remarkable experimental researches. After the

matter had lain for a time in this state in which the theoretical explanations had so large an element of individual bias in them that they could not be understood by most investigators, the entire theory was taken up anew by Maxwell in the light of Faraday's speculative discussions and reduced to a new mathematical form. In this way it finally became clear that Faraday's original conceptions had in them all the clarity of mathematical precision.

But it was the next generation after Faraday which first understood properly the range of his ideas. So is it likely to be ever with thinkers of the most marked individuality; so has it been preeminently among British scientists. As another example witness the case of Newton, whose work was first thoroughly appreciated by the following generation and in another country than his own.

In this respect the English are in most pronounced opposition to the Germans, while in some ways the French occupy the intermediate ground between them. Of these three countries which have led in scientific development it seems to be the impartial verdict of history that we owe to France the largest number of works perfect in form and substance and classical for all time; that the greatest bulk of scientific work, at least in more recent years, has been produced in Germany; but that the new ideas which have fructified science, in earlier times and also in the nineteenth century, have arisen more frequently in England than in any other country. In the second half of the nineteenth century the three leading ideas of science were probably the law of conservation of energy, Darwin's theory of descent, and Faraday's conception of electrical phenomena particularly in the more generally intelligible form which Maxwell gave to it. The latter two of these arose definitely in England; and the work of Joule on heat went a long way toward the fuller announcement of the first by Helmholtz. All three of them have been worked out with the definite cooperation of scientific investigators in all countries.

At the beginning of the nineteenth century the spirit of exact science, so far as it belonged to any large portion of the educated population, was domiciled in Paris. In such an atmosphere scientific writings took on the form of elegant literary productions. From Paris the spirit of interest spread into all countries and leavened the thought and literature of the whole world. In the country of its origin this elegant literature has maintained the traditions of its early development. In England it has been modified by the spirit which magnifies the individu-

ality of each thinker. In Germany it has taken the direction indicated by the great organization of thought there. Most German investigators stand under the guidance of a few leading minds. Their contributions to thought fall, therefore, into a few important schools in which all their researches may be ordered.

To this general statement there is one marked exception. At least one of the great intellects of Germany worked in isolation very much like that which forms the rule in England; and it is worthy of note that he is without question the greatest man in his field produced in Germany and in every respect one of the foremost men of thought in the world. I refer to Gauss, the self-taught mathematician, a thinker whose work was not well understood and appreciated by his contemporaries. But the one notable exception leaves intact the general rule that the spirit of investigation in Germany has generally manifested itself in the labors of organized bodies of researchers.

The observation of such definite national differences, particularly that between England and Germany, brings forcibly to our attention the question as to the outward circumstances under which scientific investigation will flourish best, especially for extensive periods of time or in the long run. The two kinds of activity, that in which the workers are joined together in more or less compact bodies each of which is engaged in developing one general class of ideas and that in which the individual researchers labor in isolation pursuing separately their several inclinations, presumably have their characteristic advantages and defects. To know what these are is a matter of importance both to the nation and to the individual investigator.

Let us suppose that a particular science is in the situation of having its main general ideas already at hand and that it is confronted with their detailed development as the work next to be considered. It is clear that this is a situation in which organization of effort is going to count for efficiency. It is then relatively easy for a man of initiative to direct the researches of several less gifted collaborators. A number of investigators thus working together in unity instead of isolation afford much assistance and stimulation to each other and accomplish in a short time what otherwise would require a much longer period.

In a condition of this sort German science in recent years has been far more efficient than that of any other country, while of the four or five leading nations England has probably profited least by organization of effort. In British science generally we are struck by two things: the individual greatness

of certain separate investigators, and the meager results achieved by all others. But in Germany we see everywhere the detailed development of particular theories and the accumulation of large masses of published results, greater in body than that produced in any other country, while in France and Italy and America we find a state of things intermediate between the extremes represented by Germany and England.

Organization of effort has advantages aptly illustrated by the achievements of German science. But there is at least a reasonable question whether it may not also have its drawbacks, whether there is not a measure or type of organization that hinders individuality and inhibits original ideas or points of view.

To some thinkers it has seemed that rare combinations of insight and perseverance and the skill to penetrate to the heart of nature are more likely to spring up among a people opposed to highly developed systems of thought and organizations of effort and given much to emphasizing the individual and his separate achievements. Such an idea seems to be borne out by the continued fruitfulness of England through many generations in the production of fundamental and guiding ideas in the development of science, particularly since she has in this respect apparently surpassed every other country.

Discoveries in England emanate most frequently from the depth of original genius in intimate communion with nature. Such a thinker is far enough separated from others to allow nature to work out her own impression upon him, so to speak, with less interference from the inertia due to fixed habits of thought and the preconceptions of contemporary science. There is no large university system in England eager to nurse and develop new talent and engulf all its energy into the common whirlpool; and English thinkers, therefore, in greater proportion than those of other countries, live in intimate communion with nature. They are thus the most likely of all to develop the new idea of fundamental importance.

Openness and plasticity of mind, even to age, is a general characteristic of men of genius. A desire for truth is their fundamental possession and they are not deterred from its pursuit by petty inconsistencies. Socrates was delighted when confuting others; and, if found in error, was no less pleased when confuted. In his mind no evil was so great as a false judgment concerning the just and the unjust.

Radical changes of opinion have not infrequently taken place in the gifted man late in life. At forty-seven years of

age Dryden in 1678 produced "All for Love," writing the play for himself rather than for the public and basing it on a new dramatic theory which he had evolved during an interval of rest from writing. Cayley turned to the study of law at twenty-five and after entering upon its practice changed his field of activity to become one of the great mathematicians. Not till the age of forty-nine did Cowper find out that he could write, and then for a time produced volume after volume which his readers have learned to dwell on with affectionate appreciation.

In genius there is nothing static. In every aspect it is dynamic. Thought is not fixed; it is in constant ebb and flow. Everything is afloat and no conservatism is safe. The talk of a man true to his individuality tears from its moorings all thought among his associates. However well things may have been set up before he speaks, they need to be set up again afterwards.

Truth-bearing ships may not rest at anchor where a genius is present; they must go forth upon voyages to the outermost bounds of thought. Inoculated with the ferment of his mind, they will deliver new and powerful knowledge in the remote regions, kindling everywhere a fresh illumination of beauty. In their moving hither and thither will be much profit of valuable exchange. The bread of life shall they bear to the needy, and return the wine of new truth to the out-sender.

In a few individual cases genius has seemed to be almost universal. Aristotle was learned in all the lore of his time and made fundamental contributions to thought in many directions. Poincaré was a leading investigator in every division of mathematics at a time when the subject was generally esteemed so vast and diverse in its parts that no man could be properly acquainted with all of its essential developments.

At the opposite extreme there have been men of high achievement in a narrow channel of activity whose work was magnificent in its proper region, but out of it was stupid. With the heroic meter Pope was a dexterous genius, but outside of his habitual forms he was helpless and indeed even insensible of his incapacity.

Among men of research this is the day of narrow specialization. Numerous workers achieve notable advancement in a narrow field and yet are not broad enough in view to estimate properly the bearings of their own results. They can do a work of value only because a greater mind has dealt with the whole problem and has made apparent the need of development

in certain phases. Research will never be able to dispense with the man of wide outlook who must do the fundamental work in the advancement of knowledge.

In the earlier days much of the activity of genius was demanded for war and government. The Roman temple of Janus, which was open during war and closed during peace, was shut only four times before the Christian era. But war with occasional peace among the ancients has given place among the moderns to peace with occasional war. For a generation prior to the Great War in Europe the activity of genius had been largely liberated for use in science. Coincident with this liberation was the most wonderful development of knowledge yet witnessed in the world. Man obtained a greatly increased control over nature and her forces; and the rapidity with which he extended his conquests far exceeded the highest expectations. Let society release anew her men of genius to pursue undisturbed each the matter of his own delights; and they will soon come again bearing the booty of peace and the rewards of thought, enriching life with enduring conquests of surprising grandeur.

Only one other period in the history of the world can be compared in its enormous advances in thought with the period of the present, namely, the age of Pericles in ancient Greece. The earlier period was characterized by the astonishing concentration of the wonderful development in the single city of Athens; the later period by the widespread advances in both Europe and America, depending on a collaboration of effort and unity of interest not before manifested in the history of thought. But these two developments, widely separated as they are in time and springing up under different world conditions, have this common element that they arose during a period of peace when genius was released from the concerns of war and was free to pursue its own more congenial interests.

Within the last one hundred years scientific research has opened up many new types of problems. It has found out how to reach with observation and measurement large classes of phenomena more intricate than any which were witnessed or even suspected in earlier times. It has sought by new methods the more hidden forces and conditions which make up and govern our everyday life. It can hardly be supposed that the science of one or two generations has found the best interpretation or explanation of all these facts, especially since relatively so few persons have been able to live in intimate daily com-

munion with these novel and till recently hidden aspects of nature.

It seems therefore that this is an age which, while not neglecting the development of detailed results, is peculiarly one that should look with favor upon deep individuality and the consecration of the man possessing it to a life of intimate and daily communion with phenomena—a communion in which, as far as possible, he shall let nature speak her own language to him in her simplicity and unimpeded by the foreign accent and construction of our scientific jargon. It appears that in this way one has the best expectation of coming to a new and more penetrating vision.

In order that our research into nature shall be most effective in the long run it seems therefore to be a matter of the highest concern to keep unimpaired the deep individuality of those who live much alone with the intricate phenomena of the new nature revealed to us by contemporary observation. The continual presence of such spirits upon the planet affords the highest blessing which it can receive.

This interaction of individuality and organization presents a threefold aspect, appearing in its relation to the whole world of thought, to the activity of a single nation, and to the plans and purposes of the individual. Perhaps the problem for the world at large is best solved by that partial national division of labor which has existed heretofore and which is exhibited in a most marked manner by the contrasts of German and English scientific work. To the individual, particularly to the young researcher just finding himself and his most suitable field of interest, the problem appears in a somewhat different light.

For him the question often presents itself in this way: In a range of ideas already marked by the individuality of another and being worked out in detail from a well-defined point of view he sees a number of problems which interest him and into the solution of which he could go with zest and enthusiasm; but he sees that, for the present at least, this would be to merge his individuality in that of his predecessor. On the other hand, he may see or may desire to seek less well-defined fields of investigation which are awaiting the impress of a new individuality to bring to life their dormant possibilities. Into one of these he may enter and reduce to order, slowly at first and more rapidly afterwards, the chaos which he finds there. The first procedure will usually bring him into earlier notice; for among those ideas which are well-defined and those problems which are clearly set he will the more readily penetrate beyond

the boundaries of present knowledge. But if he starts in the latter direction, though he may move things less promptly he will push them much further if he succeeds at all in getting them effectively into motion.

The more a domain demands originality for its exploration, the fewer are those individuals whose courage and persistence will enable them to penetrate it. It is better for a man to do the smaller work well than to fail entirely at the larger; but it is a more profound tragedy if the man of higher force does not find himself and therefore never applies himself to the greater problems which he might solve.

Thus the young researcher is confronted with a situation potent in its influence upon his life and the value to mankind of his labors; and between the two possibilities he must choose, either consciously and with foresight or unconsciously under the force of circumstances. Let him remember that the choice is to be made in the light of the character of service which his life devotion to constructive thought is to render in the progress of mankind.

The work of highest value can be done only as an expression of the most marked individuality. Let the beginner keep this ever before him as a fundamental principle. If his achievement is to have any first-rate qualities it must be through his allowing nature to write herself into his thought unimpeded by preconception, however hidden. The Universe honors nothing so much as the man who stands on his feet without the prop of contemporary or predecessor; and to no one else are her secrets so readily revealed. Every young researcher must choose for himself whether he shall stand in the place to receive this greater illumination or enter upon the less inspiring labor of developing already existent ideas.

The man of highest genius respects his work and does it nobly not only because it is of great value to mankind but also for a reason more important to him individually, namely, that it is an expression of himself and a means of developing him into that which he should become. He does not compare it with that of others as to value. It is a thing to stand alone and be judged of itself. With him is no concern for greater or less of genuine achievement. A realization of the best that is in him is all that he can accomplish; and he is unwilling to do what is less or different. The past and the distant, the near and the contemporary, delight him as commentaries on his own experience; but for himself he seeks primarily the noblest self-expression, whether in the production of art or in

the creation of scientific truth. When a country does not find its ideals at home but draws them from abroad, it builds nothing worthy of admiration or study. When an institution, as of learning, looks elsewhere for its inspiration and not to its own men and environment, it is dead and can not lead or inspire in the way of knowledge. When an individual draws his problem from another individual he has already made himself of second rate or lower in research. But when a man takes up a problem that appeals to him or an institution plans a work which grows out of its place in its environment or a country according to its circumstances builds up what interests its own people, each does a work of fundamental import and becomes a source of instruction and inspiration to mankind.

The greatest need of every generation in science is the man who knows current theories and tendencies and yet thinks from a center of his own, the course of whose activity is spontaneous and free as the flow of a rivulet, adjusting itself with as little effort to the inhibiting bounds of his environment. He is the perennial fountain of life and power. Primarily he is concerned not with the impressions which things make on the minds of other men, but with what they make on his own. He gives place to the opinions of others only as a sort of commentary on his own thought, as the scholar's annotations are intended to elucidate the meaning of the master in the text. His business is not to declaim on the beauties which others have attained to, but to find a new and deeper beauty underlying them, to come a little nearer to the marvelous processes of nature.

Every one transfers something of himself into his perception of the matter. If he should give an accurate account even of his most unbiased observation he would not say, It was so and so; but, rather, Thus it appeared to me. However fully preconceptions and prejudices are laid aside, there is one thing unrelated to the event which the observer can not put away, namely, the observer himself. If one is sincere and thinks from a center of his own, everything will take somewhat the color of the beholding eye, just as the world appears red when seen through red glasses.

It is impossible for one to come to the study of any class of phenomena or range of ideas without bringing his past experience and the inertia of his previous way of looking at things. Even natural science has found no way to avoid this. At best one can only reduce to a minimum the influence of prejudice and the inertia of preconception.

This obtrusion of the individual into every result of observation and thought has the most intimate connection with the meaning which should be attached to scientific truth and research. The characteristics of human thought and human sense impressions determine science quite as much as the external phenomena which are being studied. We possess a small number of special senses quite limited in the range of *quality* of impressions which they can give to us. Any particular one of these special sense organs, whatever the source of the stimulus, gives to us the same quality of sensation. Through the optic nerve, for instance, however it may be excited, we receive only sensations of light. Now it can hardly be supposed that nature possesses just a few qualities and those alone which we are able to perceive. Moreover, we know definitely that a single sense can not distinguish in many cases between phenomena of the most diverse kinds. Is it not then reasonable to conceive the possibility that phenomena in general exhibit many aspects, intrinsically very different, which we are not in the least able to distinguish even with the use of all our special senses? If this be true our science must in the end be very remote from the actually existent phenomena which we seek to explain. In other words, all our scientific hypotheses must be shot through in all directions by the peculiarities of the mental constitution of those who build up this science. Thus the latter is deeply colored not merely by individual, but by racial characteristics.

In all this is no cause for regret. We build our science for its value to us in ways both utilitarian and esthetic. For this it is quite sufficient for us to ascertain merely the invariant and permanent elements of the impressions made by phenomena upon the total human organism. Our progress will be greatest when we come in our explanations as closely as possible to the way in which the new phenomena would impress one who suffered least from the inertia of preconception. In other words, our progress will be most fundamental, other things being equal, when many individual researchers are moved primarily by that interest which springs from deep individuality. In this way we will have most consistent attention to the problems which lie closest to hand.

To consider first and primarily the problem nearest to hand is a concern not merely of the individual. In our country, particularly, scientific investigation carried on largely by groups of men connected with the institutions as such should develop in some measure the matters which are suggested naturally by

their relations to the varying bodies of supporters. In like manner the country as a whole should find some problems of central importance pertaining to the national life and thought in a way not in evidence elsewhere.

In the state university particularly we should find a zeal for research pertaining directly to the interests of the commonwealth supporting it. This should not take a too narrow form and would lose ultimately if it did; but it might well be adapted in a broad way to the demands of local interest.

This, however, could not affect all departments of thought; for some are essentially universal and non-local in character. Moreover, it should not be allowed to dominate all elements of thought in any department. This would be a narrowness fatal to the best interests. But in every department of most institutions (if not all) it is probably desirable to bring about the development of a local atmosphere, so to speak, favorable to concentrated effort along certain lines, but of course not antagonistic to any general trend of progress. No department in any one university can well represent every phase of the development of its subject; but it can represent a proper variety and at the same time a certain measure of continuity and deep relation of the particular fields primarily developed by it. In some cases at present our institutions are losing by too much separateness of effort in a particular environment, sometimes going so far that creative men in the same department are unable to understand the character of work produced by each other. It seems that such a situation as this should exist only in very rare cases, if at all. A greater solidarity of effort would doubtless further both the ends for which the department exists, namely, the creation of truth and the dissemination of truth.

The greatest example in history of a nation which set itself to work on the problems arising spontaneously out of its own interest is afforded by the city-state of Athens in the fifth century before Christ. Here, to begin with, the people built up a form of government which did not copy the laws of any neighbor. They thought things out for themselves from their own point of view and were most pleased perhaps when their speculations resulted in conclusions contrary to those previously reached. There was a marvelous openness to new truth. Strangers might come into the city at will, teaching whatever doctrine they would and carrying away with them the new truth gathered from the thinkers of the city. The Greek was calculating in preparation, daring in deed, and untrammeled by preconception when his logic led him to new or strange conclusions.

Through Pericles they said of themselves, "We are not angry with our neighbor if he does anything to please himself." On the other hand, it was expected that each would work out his own pleasure and contribute to the general good by whatever means pleased him best. He should be spontaneous and give an expression of himself in all things that he did. Under such circumstances in one century the city of Athens "gave birth to more great men of the first rank than the whole world has ever produced in any equal period of time."

Great achievement is intimately bound up with spontaneity of interest and effort. Science truly is international and profits much by the interaction of one people with another, even to the extent of obtaining fundamental values in this way. But the primary need is that each nation shall set about its part of the common problem in a way of its own, allowing its national individuality full freedom for self-expression according to its peculiar bias. Otherwise its attainments are a mere appendage to those of another people and contribute but little to the general good which would not have been as well developed if that nation had never existed. And so it has come about justly that history has recorded permanently but little concerning any civilization which did not develop from within. Likewise no national contributions to science can be of great and abiding interest unless they spring up essentially from the life and thought of the nation itself.

In order that we may have the greatest development with the most important consequences we must have abiding with us in research the spontaneity of the nation, the institution and the individual; and the greatest of these is the spontaneity of the individual.

THE ROMANCE AND THE TRAGEDY OF SNEEZING

By Dr. WILSON D. WALLIS

SAN FRANCISCO

FROM time immemorial the sneeze has been deemed worthy of notice and has elicited some form of salutation from bystanders or some expression from the agent. The phrase, "not to be sneezed at," has behind it an importance attaching to the act of sneezing to which the whole human race bears witness. Even children notice it as something peculiar and have sayings of their own, such as, "Scat!" or "Shoo!" The origin of the importance attaching to sneezing is thus a question of psychological import as well as one of cultural diffusion.

As W. R. Halliday has remarked,

> It is *per se* a startling phenomenon to find the body, which in normal action is the instrument of the owner's will and intention, behaving in a way independent of his desire or volition. Simply because it is involuntary, the twitching of the eyelid or the tingling of the ear must be miraculous. And primitive man finds a significance in everything which attracts his notice, particularly in cases where there is no obvious cause.

This is good psychology and an array of facts can be adduced to prove the point. Before returning to the interpretation of the beliefs attached to sneezing, it will be well to describe some of the customs associated with it. The first instances will be cited from the classical cultures and from our own civilization, after which we will review the evidence from savagery.

Ancient Greece.—The ancient Greek greeted a sneeze with the words, ζῆθι, Ζεῦ σῶθον, "Live, Zeus preserve thee!" Aristotle declared the sneeze an honorable acknowledgment of the seat of good sense and genius. Accordingly, when a bridegroom sneezed an observer remarked, "Some good spirit sneezed out on thee a blessing"; and Penelope remarked, "My son has sneezed a blessing on all my words." Sneezing was the indication of life first shown by the man primeval endowed by Prometheus with living spirit. The custom has been handed down by the Greek Adam to his descendants.

Rome.—Petronius, Apuleius and Pliny tells us of the Roman custom of saluting one who has sneezed, and Plutarch declares that to sneeze before a naval battle betokens victory. The be-

lief was current among the Romans that when the Dogstar arose, the wild beast, which the Egyptians called Oryx, stood facing it steadfastly, and then sneezed, "as if it were worshipping it."[1] The Roman salutation was "Salve!" equivalent to our "May you have health!"

Persia.—In the Zoroastrian religion, according to the precepts of the Zend-Avesta, prayer is advised after sneezing. It is necessary to recite some of the sacred texts, for there is a fiend in the body. In the body is a fire, a disposition, or an instinct of sneezing; this wages war with the fiend; sneezing indicates the triumph of this disposition and the expulsion of the demon. One who hears the sneeze utters the same prayer as the sneezer.

Hindu.—The Hindu theory is that a spirit is entering or is leaving the nose. The bystander says "Live!" to which the reply must be made, "With you," that is, "The same to you," or the bystander says, "God bless you!" or, "God be praised!" —the last mentioned is borrowed from the Mohammedans. If one is beginning work and hears another sneeze, it is necessary to begin the task again. If one sneezes while praying he must begin again, otherwise his prayers will be offensive to the deity. Compare with this the English saying:

To sneeze at prayer
Is the devil's snare.

China.—In China when one sneezes he remarks: "I wonder who is talking about me!" A bystander may say, "Dai gut lai see!" "Good luck!"

Mohammedanism.—Replying to a sneeze is one of the duties recognized by the Mohammedans as among the Tarz Kafa'i, the sacred duties imposed upon the faithful. According to Abu Hurairah, Mohammed said: Verily God loves sneezing and hates yawning. If a person sneezes and says immediately thereafter, "God be praised!" one of the auditors must reply, "God have mercy on you." To this the sneezer replies, "God guide us and guide you." The nose is a dangerous retreat for evil spirits and the Mohammedan, when he rises in the morning, washes out the nose with water, for the devil has probably visited it during the night.

Jews.—A Jewish tradition states that before the time of Jacob men sneezed but once and then died—a curious swan's song. In order to preserve a memory of the happy substitution when men died from natural diseases rather than from a sneeze,

[1] Pliny, Bk. II., 40; Ælian VII., 8.

every prince commanded his subjects to employ a salutatory exclamation after the act of sneezing. The custom of replying to a sneeze existed among the Jews, whose formula was, "Tobim khayim," *i. e.*, "God (give you) life," or "Asusa," "Health." The sneezer generally recited Genesis XLIX., 18, "I have waited for thy salvation, O Lord"; and, when the bystanders blessed him, replied: "Be thou blessed." That the Hebrews probably regarded the sneeze as an indication of the coming or the leaving of the spirit is shown by 2 Kings IV., 35: When Elisha restored the Shumanite's son his return to life was signified by the lad's sneezing seven times, and then opening his eyes.

Christianity.—In early Christian times the sign of the cross was made by the sneezer, though later ecclesiastical advice was to pay no heed to sneezings. They were sometimes regarded as a momentary palsy. In vain, however, did Eligius (588–659), Bishop of Noyon, an eminent French clerical writer, admonish the Christians to "pay no attention to auguries and sneezings." Respect for them persisted, and a later tradition within the church found countenance for it by assigning its origin to an ordinance of Pope Gregory, who is said to have instituted a short benediction for such occasions. He was moved to this by the fact that a certain pestilence was attended by sneezing and these sneezes usually resulted in death.

However this may be, we find many survivals among Christian peoples of the superstitious respect attaching to this remarkable function. The Roman salutation of *Sit salutiferum* is preserved by Italians of to-day as Felicita, by the French as Bonne santé, or a "God bless you," by Germans as "Prosit!" or as "Gesundheit!" A German who sneezes while putting on his shoes accepts this as a sign of ill-luck; if he sneezes while telling something to another this is a sign of the truth of his assertion. In Esthonia if two pregnant women sneeze at the same time this is a sign that they will give birth to daughters; if their husbands sneeze in chorus this signifies that the children will be sons.

In the north of England, when one sneezes the formula is "Bless the bairn"; and children are still told:

> If you sneeze on a Monday, you sneeze for danger;
> Sneeze on a Tuesday, kiss a stranger;
> Sneeze on a Wednesday, sneeze for a letter;
> Sneeze on a Thursday, something better;
> Sneeze on a Friday, sneeze for sorrow;
> Sneeze on a Saturday, see your sweetheart to-morrow.

What the Sunday sneeze betokens we can only guess.

We probably have European influence in the belief of the negroes of Jamaica that if the nostrils itch so that you sneeze, some one is backbiting you; and also in the belief of negroes or North Carolina to the effect that if you sneeze while eating, you will hear of a death.

In Malta one says to the sneezer, "Evviva" or "Sahha!"

In England a sneeze is often greeted with, "God bless the Duke of Argyl," though this formula is an insult to a Scotchman.

Another English saying, "We are never so near death as when we sneeze," seems to indicate the idea that a sneeze is a sign that the soul is leaving the body.

In Ireland the bystander says to the sneezer, "The blessing of God and Holy Mary be on you!" or, "The consecration be upon you!" meaning, the holy water.

The Bohemian declares that should you hear a sneeze, and be unable to see the sneezer, you must say, "God make you well again." Perhaps it was a wandering soul which, by your kind formula, you have now delivered.

The "Rules of Civility" (translated from the French in 1685) declares: "If his lordship chances to sneeze, you are not to bawl out, 'God bless you, sir,' but, pulling off your hat, *bow to him handsomely* and make that observation to yourself."

In Bengal bystanders must make a profound bow in order to avoid ill-luck, and in Portugal it is still the custom for bystanders to remove the hat. Trajan, otherwise indisposed to attend to the ordinary civilities, was very punctilious in giving the proper salutation to sneezers, and expected a like return when he sneezed. It is said of the present German Kaiser that, having sneezed, and those present not knowing what to do, he remarked to those present, "I sneezed and no one said 'Gesundheit!'"

The Lower Cultures.—Having indicated the prevalence in the higher cultures of the superstitions attaching to the sneeze, we may turn our attention to similar beliefs among the lower peoples, where human nature is quite as much in the ascendant.

In Indonesia sneezing is taken as an indication that the soul is either leaving or returning to the body. The belief is widely prevalent that a sick man who sneezes will recover, since this happy event betokens the return of the soul. Among Torajas, Javanese, Battak and Dayaks, when a child sneezes its mother pronounces a wish that no spirit may take away the soul of the child. In the case of adults sneezing is a sign that friends think of them, or that enemies are attempting to injure their souls.

When the latter is the supposition, to prevent the success of these malicious designs, an imprecation is uttered by the sneezer.

If an Annamese child less than a year old is so inconsiderate as to sneeze, those present, apprehending danger, call out "*com ca*," "rice and fish," the cry which they raise when he appears to faint or when he starts nervously in his sleep.

The Melanesians, of the Solomon Islands, in Florida, and the New Hebrides, are similarly apprehensive of a child's sneeze. The Mafulu, of New Guinea, are said to have no superstition with regard to sneezing, but the Koita regard is as a sign that the soul has come back to the body. If a person does not sneeze for many weeks this is an indication that the soul is far away. In Miriam, one of the islands of the Torres Straits, when a man sneezes he accepts this as a sign that some one has mentioned his name. He immediately cracks the joints of each thumb by pressing the closed fingers of his respective hands upon the thumbs. In another of these islands, Kauralaig, it was the custom for the sneezer to make violent gestures with his hands and arms, presumably with the intention of driving away the evil influence that was seeking to take up its abode in his irritated nostrils.

Sneezing used to be in North Queensland, Australia, a far more potent thing than it is at the present day. According to a tradition current in the region of Charlotte Bay, one of the earlier heroes once gave a sneeze of such force as to dislodge from the crevice of a tree the arm of another who had not been able to disengage it. The romance of the sneeze has not entirely disappeared from that region, however, for at the present day, the natives declare, the sneeze of a man indicates that a woman is in love with him.

In Motlan when a child sneezes the mother says, "Let him come back into the world!" or, "Let him remain!" On Leper's Island when a child sneezes the people say, "Good wishes!" The soul has been away and has just returned. In Mota, under such circumstances, the saying is, "Live! Roll back to us!" The soul is being drawn out of the body through the nostrils into that other world beyond human ken. When an adult sneezes he says, "Stamp down the mischief from me! Let it be quiet!" or, "Let them say their words in vain! Let them lay their plots in vain!" Thus will the magic of his formula counteract the charm of the enemy.

In Siam those present wish the sneezer long life.

In Saa, one of the Polynesian islands, the sneezer says, "Who is calling me? If for well, good; if for evil, may I be defended!"

In Old Calabar people say, when children sneeze, "Far from you!" accompanying the words with a gesture designed to ward off the impending evil. On the other hand, the Toradjas, of the central Celebes, declare sneezing a sign that a sick person's soul has returned, and that he is recovering. In the Tonga Islands, to sneeze at the moment of setting out on an expedition is a bad omen.

> At this time Mr. Mariner, on entering the house, happened to sneeze! Immediately every one present threw down his club, for who would proceed on so important an expedition after so dire an omen! Finow's eyes flashed with the fire of rage; directing them full on Mr. Mariner, he cursed him with the most bitter curse, "Strike your god!"—and, rising from the ground, he demanded why he came there?[2]

If a Maori warrior sneezed when eating it was a sign that he would fall in battle and would be cooked and eaten by the enemy. The sneeze of a common person while eating, or when about to eat, signified that visitors or news would soon arrive; a charm should be said to avert the evil attendant upon a sneeze. To avert evil the Maori pronounced this spell when one sneezed:

> Sneeze, living Soul!
> In the light of day.
> Those on the sea are blest with plenty,
> There is plenty for the mighty lord.
> Sneeze thou!
> Baptized into life!

It was not necessary to repeat the whole charm, frequently only the first few words being recited. This charm, or another, was pronounced by the mother, to avert evil consequences, when her child sneezed. In giving a name to a child the "priest" chanted the genealogies of the male line; if the child sneezed, the name that was being uttered at this time was bestowed upon it—possibly because the ancestral spirit was supposed to be inspiring the sneeze. When the king of Sennaar sneezes his courtiers immediately turn their backs and slap their thigh, vigorously.

In the Congo, when the Mushidi, or chief, sneezes, all who hear it clap their hands loudly and shout, "Long live the King! Hail!" The oftener he sneezes the longer will be his life, a sneeze being but an outflow, or the overflow of a superabundance of life. Consequently, a paroxysm of sneezing evokes a chorus of approval. When a Bakongo sneezes some one sitting close by says, "Come quickly." If the sneezer be a child of tender years the mother calls out, "Come back quickly." This is to summon back the spirit which is supposed to be leaving the body when one sneezes. If any of the slaves buried alive at the

[2] J. Martin, "The Tonga Islands," p. 271.

death of a Yao chief should sneeze after being placed in the grave, he was spared, in the belief that the spirit had thus signified his refusal of that particular victim. Evndently, they were not in the habit of taking snuff—this would have been a life-saver.

A Gold Coast story speaks of a leaf, which, when a person smelled it, caused sneezing. "They rubbed the leaf upon the noses of the two cows. Then the cows at once looked as if they wanted to sneeze, and they rubbed the leaf on the noses of the two cows." A medicine-man attempted to restore a woman killed by witchcraft by inducing sneezing, presumably so that the evil spirit would escape—or her own return. When the king of Dahomey sneezed, all present touched the ground with their foreheads; but to sneeze in the presence of royalty was punished by a fine. Among the Ewe-speaking peoples to sneeze is a bad omen. Among the western tribes

this involuntary convulsion is an indication that something is happening to the indwelling spirit, usually that it is about to quit the body; and as that affords opportunity for a homeless indwelling spirit to enter the body and cause sickness, the omen is bad. Among the eastern tribes, though the notion of the indwelling spirit has been to some extent confused with that of the ghost-man, the old superstition still prevails.

If the indwelling spirit should leave a man when he is awake, he becomes appraised of its departure by a sneeze or a yawn. Hence the sneeze is believed to indicate that the *kra*, one of the man's souls, is leaving the body, and the bystanders always offer some wishes of good health.

Among the Tshi-speaking tribes a sneeze seems to be regarded as an evidence of something unpleasant or painful having happened to the indwelling *kra*. Hence, as the well-being of the man is indissolubly bound up with that of his *kra*, it is usual for persons to address wishes of long life and good health to anyone who sneezed, with the idea of thereby averting an independent ill.

When the king of Ashantee sneezes, every person present touches or lays the two first fingers across the forehead and breast, as the Moors did when they pronounced a blessing, and the Ashantees, invariably, to propitiate one. When the king of Monomotapa sneezed, it became a national concern. Those nearest the royal person howled a salutation, which was taken up by the antechamber; and when the horrid cry had run through the palace, it was re-echoed by the whole city.

When a Thonga sneezes, he is addressed with this good wish: "Life and sleep!" He himself calls upon the gods, saying:

I pray to you! I have no anger against you! Be with me and let

me sneeze! Let me sleep and let me see life! so that I may go by the road, I may find an antelope (dead in the bush), I may take it on my shoulders; or that I may go and kill an elephant (meaning, meet with a girl and obtain her favor). Now I say it is enough, you nose!

The sneeze of a child during one of the ceremonies is ominous.

Any man who sneezed in the presence of the Zulu chief, Chaka, was instantly killed. The Xosa says, "Qamata help me!" Qamata being either a powerful chief or some supernatural being. Other Kafirs, when they sneeze, say, "Chiefs," or, "May the chiefs bless me!"—much as people in the lower classes in England say, "Lor' bless you!" To sneeze is thought to be a very good sign. In ancient days, when a Zulu chief sneezed, all the people near would say, "May the chief live long!" or, "May he grow greater!" If a sick person begins to sneeze, the people say it is a sure sign that he is about to recover, for the spirits are pleased." If he is ill and does not sneeze the disease is a malignant one. To a child who sneezes they say, "Grow!" for this is a sign of health. In the case of an adult it is a sign that the ancestral spirits have come to the agent and he returns thanks. This is especially true of the medicine-men. The Christian Zulus say, "Preserve, look upon me!" or, "Heaven and Earth!" Elsewhere, among the Kafirs,

Sneezing is considered a very good sign, and when a small child sneezes the mother says, "Thanks, Chiefs!" thus giving thanks to the ancestral spirits who are supposed to be shown by this sign to be taking care of the child. Sometimes when a child sneezes the mother will simply say, "Chiefs!" thus giving thanks to the *amatongo* (ancestral spirits). At other times the mother says, "Throw out and you will grow well."

The North American Indians, to mention but one more culture area, have attached considerable importance to the sneeze. Among the Eskimo of Hudson Bay, when a person sneezes, he must say to his soul, "Come back!" otherwise he might become sick. If a child sneezes, the mother smacks her lips, the appropriate response of the child which she performs for it. The sneeze of a sick person, however, is a sign of approaching recovery. The Bilqula declare sneezing an indication that people are talking about one. To sneeze three times in succession was believed by the Stlatlumh to bring good luck to the person sneezing. To sneeze through the right nostril is a sign of good fortune; to sneeze through the left, a sign of bad fortune.

The Wasco associate sneezing with mention of a person's name:

The young men asked, "Who is the chief of the village?" The old woman said, "We must not tell you. If we mention his name, that moment

he will sneeze and say, 'My name is mentioned in the old house at the end of the village,' and he will send to see who is here," but the brothers insisted. At last the old woman told him, and that instant the chief sneezed and sent to the house.

The same belief is found among the Takelma, where a person who sneezes says, "Who calls my name?"

> "Thou shalt prosper," shall he say of me, "yet another day shalt thou go ahead." (That is, "mayest thou continue to live.") Ye shall blow to me,

meaning, "blow a whiff of tobacco smoke for my prosperity." Here, too,

> When a person sneezed, it was believed that his name was being mentioned by some one afar off. To prevent the evil effect to the person named of a possible mention of his name in connection with ill wishes (for words as such may have power of good or ill), it was customary to apostrophize the absent ones: "Who is it that calls my name? May ye (who speak to me) say in regard to me: 'Do thou prosper, mayest thou go ahead [*i. e.*, continue life] yet another day!' May ye blow to me!"

Among the Yana a woman says:

> May I be happy! Do you people not speak about me! Do you speak for my happiness when speaking about me!

A man says:

> May I be happy! May my legs feel light! May you people speak for my happiness! Would that you would let me alone! I bathe, and I go back into my house, and I rejoice in my eating.

Among the Dakota to sneeze once means that a man's special friend, his son, or his wife, has pronounced his name; whereupon he calls out, "My son." If he sneezes twice he exclaims, "My son and his mother." When a Crow Indian sneezes bystanders say to him, "They are calling you; that is why you sneeze," though the remark is said to be regarded simply as a joke. The Apache remarks, "Some one calls my name." The Pima pronounces the names of Earth Magician and of Elder Brother, two of the culture heroes, when he sneezes; or, he may simply exclaim, "Pity me!" as a plea to one of these two creatures. The Guiana Indians believe that during sneezing or yawning the soul is temporarily leaving the body, though what they do about it we are not told.

When De Sota, in the year 1542, was interviewing the Cacique Guachoya, the latter happened to sneeze. Thereupon all the attendants of the cacique bowed their heads, opened and closed their arms, and made signs of veneration, saluting their prince with such phrases as, "May the sun guard you!" "May the sun shine upon you!" "May the sun defend you!" "May the sun protect you!"

The Ominous Sneeze.—As we have seen, the sneeze is frequently accepted as indicative of good or of ill luck, and sometimes there is a further specification of the fortune, good or bad, to be expected.

In the island of Florida the sneeze indicates that some one is speaking about the man, is angry with him, is calling upon his *tindalo,* or personal ghost, to eat him. He accordingly responds by calling upon his own *tindalo* to take revenge on the man who would injure him. In the Celebes a man who sneezes when about to part company with friends must return, and sit down awhile in order to fend off the impending ill.

The Siamese consider it lucky to sneeze many times. They believe also that the judges of the lower realm of shades keep a book in which the name of every one is registered, and that, when this book is opened all those whose names appear on the page that is observed sneeze. Their optimism, therefore, seems to indicate great faith in a clear record on this golden book. To the Chinaman, too, the sneeze indicates luck, and the gambler who sneezes knows that he will win. In many parts of Europe to sneeze when one sees a hearse indicates that another death will soon occur in that vicinity. In India to sneeze at the threshold is unlucky. The Romans declared that when a cupid-like little boy sneezed the birth of a beautiful girl baby was thereby indicated.

The Greeks considered sneezing to the left unlucky, but lucky if to the right. When Themistocles sacrificed in his galley before the battle of Xeres, and one of the assistants upon the right hand sneezed, Euphantides, the soothsayer, presaged the victory of the Greeks and the overthrow of the Persians. When Xenophon was addressing his troops, the doughty ten thousand, and his remarks, "We have many reasons to hope for preservation," were punctuated by a sneeze from one of the attending soldiers, Xenophon paused, then resumed: "Since, my fellow-soldiers, at the mention of your preservation, Jupiter has sent this omen." Xenophon had previously profited by this omen, for he owed his appointment as general to the happy event of a sneeze to the right of him while he was making a speech. On each occasion the army accepted the omen and the men were inspired with new vigor. The custom of regarding the sneeze as ominous is as old as Homer. Evidence of this is to be found in the eighteenth book of the Odyssey:

> She spoke: Telemachus there sneezed aloud;
> Constrain'd, his nostril echo's through the crowd.
> The smiling queen the happy omen blest:
> So may the impious fall, by fate opprest.

Aristotle puzzled over the problem—And is it not enough to try the mettle of any philosopher?—"Why sneezing from noon to midnight was good, but from night to noon unlucky." St. Austin declares: "The ancients were wont to go to bed again if they sneezed while they put on their shoe."

In England, as still in Siam, much sneezing is regarded as favorable. "Two or three neses be holsom; one is a shrewd token," says an old English motto. "He hath sneezed thrice, turn him out of the hospital," was a seventeenth-century proverb, an assurance that the patient will now do well. Sir Thomas Browne recognized it as in the main a good sign and approved of the giving to persons near death a medicine which would induce sneezing—"if the faculty arise, and sternutation ensues, they conceive hopes of life, and with gratulation receive the sign of safety." If a sick person can not sneeze the disease will end in death—a belief which we have found in other parts of the world. Sir Thomas Browne assures us, however, that sneezing is bad if the patient be an unmarried girl, a widow, a barren wife, a shoe-maker's wife, a woman sick with the cholera.

The meaning attached to sneezing by European peoples is of various kinds. An unsuccessful attempt to sneeze indicates that you will lose something of value; but if you sneeze violently enough to tear a buttonhole out of a shirt, dress, or vest, riches are rapidly coming your way. It is good to sneeze while reading, when launching an argument, when about to retire, when eating—though, as to the latter, negroes declare it betokens news of a death. It is good to sneeze at seed sowing, for the harvest will be great. You will not sleep well if the servant sneezed while making up your bed—possibly because you will be amid too much dust. Two men talking business and sneezing simultaneously have cause for mutual and self-congratulation. The soldier who sneezes at the mention of an approaching battle will be on the side favored by victory. (Then may such a sneeze go forth from all the Sammies and Tommies as will blow the enemy ——! But, doubtless, they are sneezing enough.) To sneeze twice each night for three successive nights is a sign of approaching death. If you sneeze between eleven and twelve o'clock, you may expect a stranger. Husband, beware: If you sneeze while you are getting up in the morning, lie down again for another three hours, else your wife will be master for a week. Whether any worse fate awaits the husband who adopts the above-mentioned prophylactic, who can say?

To sneeze before breakfast is well; you will receive a present that day, unless it be Sunday; in which case declare Vermonters, you will hear of the death of a friend before another Saturday night. Instead of waiting until the preprandial hours of a Sunday morning, sneeze rather on Saturday night after the lights are out, and, on the following day you will be rewarded by the sight of a person whom you have never seen before—a promise perhaps more inspiring to the countryman than to the dweller in the city. If you sneeze with food in your mouth you will hear of the death of a friend; every time you sneeze at table there will be one more or less the following meal. Whether it be more or less may depend, we surmise, on whether the old Roman advice was followed—*Sternutare volens vicino obvertito vultum*—when you sneeze turn aside your countenance from your neighbor—; or whether, on the other hand, the advice was followed which is given in a book called "The Schools of Slovenrie, or Cato turn'd wrong side outward, translated out of Latin into English Verse, to the use of all English Christendome except Court and Cittie; by R. F. Gent., London, 1605," wherein we read:

When you would sneeze, strit turn yourselfe into your neighbor's face:
As for my part, wherein to sneeze, I know no fitter place;
It is an order, when you sneeze *good men will pray for you;*
Mark him that doth so, for I thinke he is your friend most true.
And that your friend may know who sneezes, and may for you pray,
Be sure you not forget to sneeze full in his face alway.
But when thou hear'st another sneeze, although he be thy father,
Say not *God blest him*, but *Choke him*, or some such matter, rather.

. . . .

Aristotle's explanation of the respect shown to sneezing is that the first men, viewing the head as the principal seat of the soul, an intelligent organ governing as well as animating the entire body, carried this respect to sternutation as the most manifest sign of life. Hence the compliments heaped upon the sneezer. Since it is a motion of the brain suddenly expelling through the nostrils what is offensive to it, it can not fail to afford some evidence of the brain's, that is, the mind's vigor. Aristotle's view is endorsed by Sir Thomas Browne.

That some peoples should attach a sinister meaning and others a favorable meaning to the sneeze is not difficult to understand. Fear of bad consequences leads to the pronouncement of a formula, a blessing designed to ward off the evil. The pronouncement of a blessing or of wishes for one's welfare may easily pass over into expectation of its fulfilment, and, conse-

quently, of benefits. Eventually the benefits are thought of to the exclusion of the threatening evils, and hence the sneeze becomes propitious. It is easy to see that a people may entertain one or the other attitude toward it; and that, possibly as the result of accidental association, particularly should it receive confirmation, some sorts of sneezes may be considered propitious and others dangerous.

Thus the explantion of the curious beliefs associated with the extraordinary phenomenon of sneezing is not far to seek, and has already been repeatedly given in the various practices already described. The soul often finds exit or entrance by the nose or by the mouth, for it is in large part identified with the breath. The breath of the nostrils is indeed the life of a man, and his life force is intimately bound up with his soul. For this reason the nostrils as well as the mouth of the dying man are sometimes held or closed to keep in the soul. This is done sometimes for the benefit of the deceased, since this soul should accompany the body wherein it has resided, and sometimes for the benefit of the survivors who have little desire to remain in the company of the disembodied spirit of him with whom they associated in life. In the Celebes fish hooks were attached to a man's nostrils to impale the soul of the dying should it attempt to escape. Eskimo mourners, or those who prepare the body for burial, plug the nostrils lest the soul which is supposed to remain with the body should find exit and follow the migratory soul of the dead to the land whence souls are reincarnated. It is not uncommon for savages, while sleeping, to cover the nostrils and the mouth, to prevent the escape of the soul unknown to the unconscious owner. Even the cultured Greeks and Romans were not averse to leaning over the dying man in order to obtain the spirit of the departed by inhaling his last breath, and so receiving his spirit into themselves.

This, coupled with appreciation of its startling and peculiar nature, is the philosophy which has given rise both to the romance and to the tragedy of the sneeze.

PHYSIOLOGICAL INERTIA AND PHYSIOLOGICAL MOMENTUM

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NEWTON'S first law of motion states: "Every body continues in its state of rest or of uniform motion in a straight line, except in so far as it is compelled by forces to change that state."

The conception of inertia is inherent in this famous definition, for that property of matter in virtue of which matter tends to maintain its state of rest or of uniform motion in a straight line, is called inertia.

Functional inertia is that property of living matter (bioplasm) in virtue of which, having received a stimulus, it continues to maintain the functional status quo ante, whether that was activity or inactivity; and functional momentum is that property of bioplasm in virtue of which the living matter, having responded to a stimulus, continues to exhibit its activity or inactivity after the stimulus has ceased to exist. Functional or physiological inertia is that property of living matter which maintains the status quo ante, namely, non-response to a stimulus tending to arouse a response (functional inertia of rest), or response after the stimulus has ceased (functional momentum).

Affectability is that property of living matter in virtue of which it responds to a stimulus either by activity or by the quelling of activity (inhibition). States of inactivity or inhibitions are, therefore, equally with activity responses to stimulation. We may express the inter-relations of these factors as follows:

A stimulus having been received, then if affectability predominates there may be either activity or inactivity; and conversely, if functional inertia is predominant when the stimulus is received, there will be activity, if activity was the status quo, but inactivity, if inactivity was the status quo. Finally, the stimulus having ceased to act, there will be, owing to functional momentum, activity, if activity was the status quo, inacivity if inactivity was the status quo. As a recent writer

in *Nature* puts it—"Responses to stimuli cannot take place instantly, neither do stimulation effects fade away momentarily."[1]

Some definite examples might be given: a stimulus is applied to a muscle at rest; the muscle does not shorten until after a "latent period" which is lengthened by cold and fatigue: here the functional inertia of the muscle maintains the status quo ante of inaction: the heart is beating when a stimulus tending to stop it (inhibit) is received, the heart makes a beat or two before it stops; here the status quo ante of activity was maintained.

If the cardio-accelerator nerves of the heart are stimulated, the heart's action is accelerated, on stopping the stimulus the heart continues to beat fast for some time before it resumes its pre-stimulant rate; this is post-stimulant activity due to physiological momentum. If the vagus or inhibitory nerve of the heart is stimulated, the heart can be brought to a standstill; when the stimulus is withdrawn, the heart remains quiescent for some time before it resumes beating; this post-stimulant inhibition is due to functional momentum.

Both properties, affectability and functional inertia, coexist in bioplasm, at one time one predominates, at another another. Thus, in the heart cycle during systole, functional inertia predominates, for a stimulus given during systole is totally disregarded (refractory period). During diastole, affectability predominates, and a stimulus given during that phase elicits a small systole (extra systole). This functional inertia during systole makes it impossible to tetanize the heart.

These limits set to metabolic possibilities are due to the possession of functional inertia, a property possessed contemporaneously with affectability. Thus, as I wrote in 1908, the manifestation of life at any given instant is to be regarded as the resultant of two coexisting but physiologically opposite functional propensities or capabilities; the degree of whose relative intensities conditions the character of the particular manifestation at the moment; response if affectability be the predominating condition; non-response if functional inertia be the characteristic state. Non-correspondence with environment is the keynote of protoplasmic inertia; independence of environment, disregard of stimulation, inaccessibility to external influences, insusceptibilities, resistances, limits to powers of response—a holding on the even tenor of the metabolic way.

Limits to rates of activity, superior limits to rhythms, are inertial. Cilia bend to and fro at about ten to twelve a second

[1] *Nature*, January 3, 1919, p. 354.

at ordinary temperatures; but on being heated can not do so faster than twenty a second. Thus the (rabbit's) heart heated can not perform systoles at a greater rate than six a second, our respiratory center can not discharge impulses at a greater rate than about two per second, we can not perform twitching movements of the fingers at a greater rate than about twelve a second, nor articulate more than about ten to twelve syllables per second, and so forth. Professor Sir A. Schäfer, Professor Waller, Professor Starling, Sir S. Sharkey and the late Professor Mosso, all use the term "inertia" as referring to nerve cells.

Closely allied to inertial limits are inherent rhythms, as demonstrating a disregard of environmental stimuli. For instance, the "post-tetanic tremor" (D. F. H.) in which a muscle twitches at about four to six a second, although it is receiving stimuli at a rate which, when it was unfatigued, produced in it complete tetanus.

Protoplasmic inertia is the physiological counterpart of affectability. Dead organisms have no affectability at all, but infinitely great functional inertia. Those in latent life (Scheintod) have very little affectability and much functional inertia. Thus the dried Rotifera, Tardigrada and many ova amongst animals; and seeds, resting (winter) buds and frozen bacteria, etc., amongst plants, are all cases of insusceptibility due to the possession of a high degree of functional inertia. Seeds, for instance, have little affectability; they will give an electric response to a powerful condenser discharge sent through them, but otherwise their inertia is extreme. As a French writer puts it, they are "tombés dans un état d'inertie complète." Writers in clinical medicine clearly recognize the condition which I am describing as a fundamental property of protoplasm. Thus Dr. R. W. Leftwich[2] writes of a type of coughing that "persists for long after the condition which produced it has passed off."

My early critics misapprehended my position in one or two respects; some complained, for instance, that functional inertia explained "too much." They might as well have complained that affectability explains too much. They failed to recognize that both these fundamental, vital properties—affectability and functional inertia—are coexistent and omnipresent, that there is no portion of living matter that does not possess

[2] "Aids to Rational Therapeutics," R. W. Leftwich, M.D., London, Bailliere, Tyndale, Cox, 1918, p. 6.

some of each property, and that, therefore, between them they must "explain" the whole of life. Of course no property of protoplasm "explains" life; but all manifestations of livingness are dependent on the simultaneous possession by living matter of two complementary and equally fundamental properties, affectability and functional inertia. At no time in the life of the organism is there absolutely only one of these properties in existence; in death functional inertia is maximal and affectability has disappeared. The converse of this, a state of infinite affectability with no functional inertia, is not known now and here on this globe.

Physiological insusceptibility may be absolute, as in such cases as light waves falling on the auditory nerve or sound waves on the optic where there are no responses whatever. These and similar conditions might be called absolute functional inertia; but inasmuch as the stimuli are not only heterologous but perfectly inappropriate, these cases need not further detain us. The case, however, of the stigma of a particular species of plant being insusceptible of fertilization by the pollen of some other species is another case of the same sort of inertia.

Certain idiosyncrasies may be related to the two properties of protoplasm thus—extreme "susceptibility" towards a poison or drug is due to extreme affectability towards it, whereas a high degree of resistance to a poison or drug is the outcome of a relative functional inertia towards it.

A tissue performing some chemical transformation may exhibit functional inertia under one of its many aspects; the tissue or organ may exhibit a longer or shorter latent period after the exciting stimulus has been received; it may maintain its own particular rate or pace of activity; it may produce its own proper chemical transformations after the stimulus has ceased to exist; and, finally, it may be concerned in such an activity as the excretion of uric acid, which is in itself regarded by some physiologists as chemically a vestigial process. On this view, the excretion of uric acid by the mammal is a survival of a chemical activity characteristic of an avian ancestor. The excretion of this acid is thus an example of the maintenance of a chemical status quo ante.

Physiological momentum is strikingly shown by certain vegetable organisms. The opening and closing of certain flowers goes on for some days after the plants have been placed in the dark; "the seasonal periodicity is exhibited by deciduous

trees when removed to countries where the vegetation is evergreen."[3]

Professor W. A. Osborne, of Melbourne, Australia, found that his diurnal curve of temperature maintained its subtropical character for some weeks after he had been living in the temperate zone.

The time of onset of menstruation affords another example; the Hindoo girl begins to menstruate at twelve or thirteen, the English at fourteen to seventeen years of age; an English child taken to India begins this function not at the age appropriate to the native race and the hot climate, but at that indicative of her own.

Birds in captivity, removed from all circumstances that might be supposed to indicate or necessitate journeys, nevertheless become restless at the return of the season for migration.

All activity of organs after the death of the body as a whole (somatic death) are examples of physiological momentum; thus, the possibility of the perfused heart beating, of the liver secreting bile, of the skin glands and hairs surviving, of nerve fibers remaining active, and so on, are all examples of it.

The over production of anti-toxin after the stimulus (toxin) has ceased to operate has been repeatedly quoted by medical writers as a striking example of physiological momentum.

The relations of functional inertia to heredity are intimate and obvious. If functional inertia is a property of cells, and therefore of tissues, organs, systems and organisms, it must also belong to the individuals who compose the race. It is responsible for racial characteristics, it moulds national destinies. Thus, races with much functional inertia, which learn anything new with the utmost difficulty, remain in their racial *status quo* century after century. "Oriental inertia" is, in fact, the term universally used to describe their state of non-receptivity, their holding on in the straight line of their ancestral path.

There is an inertia of character in the family, clan, nation or race. As I wrote in 1908,[3a]

> By environmental stimuli acting through affectability we become educated or trained to be what under other circumstances or in another environment we might never have become; whereas through functional inertia, character is inherited and certain tendencies become innate, and one's individuality unfolds as the underlying ground tone of the life, until we are what we could not in any way whatever help becoming.

[3] R. A. Robertson, "Functional Inertia in Vegetable Organisms," *P. R. S. E.*, 1901–02.

[3a] The functional inertia of living matter. London, Churchill. 1908.

By internal momentum, the "person," character, individuality, is forced into manifestation in opposition, it may be, to parental objections, the teacher's frown and the disapproval of society generally. It was not affectability in the Bourbons which caused them to be described as learning nothing and forgetting nothing. Functional inertia preserves race peculiarities and guarantees constancy of type through very long periods of time. As Huxley well said, "any admissible hypothesis of progressive modification must be compatible with persistence without progression through indefinite periods." He then proceeds to remark that no order of fishes is known to be extinct. Huxley accepts Haeckel's view that "living matter is urged by two impulses, a centripetal, which tends to preserve and transmit the specific form, and which he identifies with heredity, and a centrifugal which results from the tendency of external conditions to modify the organism and effect its adaptation to themselves. The internal impulse is conservative and tends to the preservation of specific or individual form."

Huxley has described these two tendencies in living matter so well that I must quote from him once more.

The tendency to reproduce the original stock has, as it were, its limits, and side by side with it there is a tendency to vary in certain directions, as if there were two opposing forces working upon the organic being, one tending to take it in a straight line, the other tending to make it diverge from that straight line, first to the one side and then to the other.

The former tendency I attribute to functional inertia, the latter, of course, to affectability.

Professor J. Arthur Thomson, of Aberdeen, is very emphatic when he writes,[9] "in the light of the fact that frequent as variations are, hereditary constancy or inertia or persistence of specificity is even more marked." He is constrained to use even the very term "inertia," and entirely in my sense, in his valuable and exhaustive monograph on "Inheritance."

Psychic Inertia and Psychic Momentum

Inertia and momentum are as clearly demonstrable in the things of the mind as they are in those of the body. Sensations, concepts, emotions, ideas—all mental states—would seem to possess functional inertia and momentum as distinctly as it is possessed by the underlying substance of the nervous system. (I shall not now digress to debate the subject of the causal interdependence of the activities of the nervous system and mental or conscious manifestations, although I may remark that I am a thoroughgoing interactionist.)

Dealing in the first instance with sensations, the argument somewhat as follows. If functional inertia and functional

[4] *Jour. Royal Micros. Soc.*, 1916, p. 448.

momentum are properties of cerebral protoplasm, they must also characterize sensations which have the activity of cerebral protoplasm as their causal physical basis. Professor J. McKeen Cattell long ago put it so well that his words may be quoted. "Inertia is a property of our sense-organs. The molecules of the cells are only set in motion after they have been worked upon by a stimulus of a certain strength for a certain time, and the motion continues after the stimulus ceases." Here Professor Cattell recognizes both psychic inertia and psychic momentum. The latter, indeed, had long ago been described by Hobbes (died 1679) in these words: "Like water troubled, an organ of sense will remain in motion after the removal of the exciting agent." Haller (who died in 1777) wrote, "these" (mutations of cerebral substance) "persist for a long time after the cause which gives rise to them has ceased to operate."

Psychic momentum underlies all those sensory phenomena known as positive after-sensations. The positive after-image is due to this psychic momentum, advantage of which is taken in the kinematograph in which a series of brightly illuminated instantaneous photographs of moving objects produce, by their retinal persistence, the illusion of continuous movements. If each impression vanished instantly, then there would be intermittency or flicker and no fusion of effects, as does occur when the photographs are run through too slowly, giving time for the after-images to fade away. But any given image "outlives" its stimulus in virtue of its functional momentum, and, fusing with the next oncoming image, produces the desired illusion of continuous action and not what it really is, a series of a large number of instantaneous views of moving objects.

On the material side, the positive after-image is due to the functional momentum of the retino-cerebral substance. To its existence is due the fact that a disc half white and half black, rotated in front of us, appears grey; or one half red and half blue, purple; and so on. The fusion of effects is only possible because of persistence of retinal impressions, and these are the results of physiological, psychic momentum.

Similarly, we *feel* contacts, pressures, pains, etc., long after the sources of these sensations have been removed. Who has not still felt his "rubbers" on his feet for some time after he has thrown them off?

Professor Sherrington is constrained to use the very word "inertia" in his article on "Skin, and Common Sensation"[5]

[5] "Text-Book of Physiology," edited by Schäfer, London and Edinburgh, 1900, Vol. II., pp. 998–999.

thus: "The inertia of the pain apparatus and the inertia of the organs for pain seem particularly great." Writing of pressure applied to the skin, the same author writes, "Pressure applied to the skin makes a sensation which does not subside—the sensation continues."[6] This is psychic functional momentum.

Four years after my views on functional inertia had first been put down on paper, I came across (1903) a notable lecture delivered in 1818 by Michael Faraday to a society in London known as the "City Philosophical Society." Speaking of inertia, Faraday says:

> Whatever is in motion is by it retained in motion, and whatever is at rest remains at rest under its sway. It opposes every new influence, strengthens every old one. Is there nothing in the human mind which seems analogous to this power? Is there no spiritual effect comparable to this corporeal one? What are habits? Old prejudices? They seem something like a retention in a certain state due to somewhat more than the active impulses of the moment. . . . The mind seems to remain in the state in which it is, and the words which enunciate parts of our natural law will describe exactly the effect . . . to illustrate at once the force of mental inertia.

Continuing, Faraday writes: "Apathy will represent the inertia of a passive mind, industry that of an active mind." The expression "inertia of the mind" frequently occurs. Enough has been quoted to show that Faraday had clearly before him the reality of mental inertia and mental momentum. The well-marked tendency to do what has been done before, to continue doing what you have just been doing, to yield to the familiar, to habit, is nothing else than the expression of psychic momentum. Every day we have examples of it; some one reads from the newspaper, "thirty or forty" when it was "thirty or fewer" that was written. Oliver Wendell Holmes alleges that not one in ten people can read Judges XV: 16 correctly; the verse is, "And Samson said; with the jawbone of an ass heaps upon heaps, with the jaw of an ass have I slain a thousand men." Nearly every one reads "jawbone" for "jaw" in the second clause.

Mental inertia and mental momentum must be as universal as mental affectability.

Bigotry, superstition and extreme dislike to change are expressions of psychic inertia, while obsession with an "idea" and fanaticism are those of psychic momentum. The riots which occurred in many parts of England on the introduction

[6] *Ibid.*, p. 925.

of machinery, and the violent protests that were raised against the making of railways in the early nineteenth century, are examples of the operation of national functional intertia.

It must not be supposed that the expressions of mental functional inertia are confined to the unreflecting proletariat; practically all the great discoveries in science and medicine have met with opposition not because they were not beneficial, but because they were new.

The discoverers of the circulation of the blood, of vaccination, of anesthetics, of the germ-origin of disease were obstructed and attacked not only by the laity, but by their own professional brethren. Galileo, Harvey, Jenner, Simpson, Pasteur and Lister were worried, ridiculed and persecuted, as all students of the history of discovery know.

Many writers have identified habit with inertia, thus Frank Buckland wrote of the "vis inertiæ of habit" in fish.

Of course it is in religious systems that we find the most perfect examples of psychic inertia and of psychic momentum. As Herbert Spencer put it, "Religious dynasties have extraordinary powers to resist change." National psychic inertia is expressed by national religion. The stolid, fatalistic and unprogressive Oriental is merely expressing his racial, mental inertia.

By psychic inertia instincts, capabilities and incapabilities, predispositions to all manner of activities and non-activities, are carried over into the next generation where they unfold themselves and maintain themselves, not only not in harmony with the environment but often in opposition to it. The environment in matters psychical is chiefly constituted by education and all that that means.

Educability is psychic affectability, ineducability is psychic inertia. It is this that Professor Ribot alludes to when he says that heredity has set a limit to the education of the negro. This is only another way of saying that it is the misfortune and not the fault of the negro, as it is with all who have inherited ineducable disabilities.

This pessimism has been extended by Monsieur Guyau when he says that education is powerless to modify to any great extent the radical temperament or character of the individual. According to this view, the criminal as well as the poet *nascitur non fit,* the child's whole moral destiny is contained within it while as yet unborn.

We may take the hypnotic trance as a good example of

psychic inertia, in that phase of it in which profound anesthesias and analgesias are developed so remarkably and so mysteriously.

The Origin or Genesis of Functional Inertia

All the properties or powers of living matter are not possessed exclusively by living matter. Certain properties or powers are characteristic of living matter and are not possessed by matter that is not living. Thus, the powers of reproduction, digestion and assimilation, are characteristic of living matter and are not shared by matter that has not ever lived. Crystals, for instance, do not reproduce themselves, nor can they incorporate material dissimilar from their own substance; but it is just these things that living beings can do. The "growth" of a crystal has nothing in common with the "growth" of an organism except the name.

Non-living matter is, however, affectable; if by affectability we mean the power of responding to a stimulus. Thus, gunpowder is highly affectable towards a spark, in that it will respond to such by an explosion, that is, it will convert violently its potential chemical energy into the kinetic forms of heat, light, sound and molecular disruption. Gunpowder, therefore, has affectability towards sparks as "stimuli." But gunpowder will not be exploded by concussion; it has, therefore, inertia towards concussion as a stimulus; if it is the "function" of gunpowder to explode, then it has "functional" inertia towards concussion, but high affectability towards sparks.

Affectability and functional inertia are possessed by such kinds of non-living matter as are designed to transform energy that is, to perform functions. Another example may be taken in the case of cordite; if it is the function of cordite to explode, then it has affectability towards concussion which causes it to explode, but it presents functional inertia towards sparks, which merely make it burn, but not explode.

It is, therefore, highly probable that just as the affectability of living matter is foreshadowed by that of non-living matter, so physiological inertia is foreshadowed by the inertia of non-living molecules.

As a pure speculation, protoplasmic inertia may be assumed to have been evolved from the molecular inertia of non-living matter and in particular from that of the carbon atom. Professor J. C. Bose, of Calcutta, has contrived to demonstrate in non-living matter such phenomena as latent period, post-stimu-

lant effects, and fatigue, on the one hand, as well as staircase responses, summation of effects, diphasic electrical variation, the results of varying temperatures and of different poisons, on the other. Such results are due to the existence of molecular inertia and of affectability respectively in the non-living mechanisms with which he worked.

Affectability and functional inertia are, therefore, not differentiae of living matter in the sense that the powers of reproduction, assimilation and excretion are. Only living matter can grow (metabolise) and reproduce itself, but both non-living matter and living matter can, under certain circumstances, respond to a stimulus, and under others, refuse or fail to do so.

Molar and molecular inertia are universal properties in that they are possessed by all forms of matter and by all mechanisms whether living or non-living which have the power of transforming energy.

Functional or physiological inertia is a property of all living matter (bioplasm) not merely by way of analogy with the inertia of non-living molecules, but because in its genesis such a property must have been derived from the fundamental property of non-living matter.

THE WHITE MAN'S MAGIC IN HOMER

By JONATHAN WRIGHT, M.D.

IN a previous essay which, as it was, occupied too much space in this journal (December, 1918), there was especially one aspect of the subject of *the foundations of belief of primitive men* to which I wished to give greater extension, but which I was obliged to pass over with a mere allusion. It was in sequence to the assertion that "all students of the dawn of history—all those who have pried into the practical life and the esoteric life of the ancient Oriental civilizations, so far as their details before the Trojan War have been revealed to us, feel that with the advent of the northern races around the Ægean Sea something almost cataclysmic happened in the smooth course of the progress of thought and emotional life, in philosophy and art and religion."

As to medicine, the remark has been made by others doubtless, but it impressed me much at first, that in the works of Hippocrates we find about as little of primitive magic as we do in the most recent professional works of modern medicine. It helps us to realize how high was that civilization from which Hippocrates drew his inspiration, the culture that had been evolved by Thales and Anaximander, by Heraclitus and Democritus in science and which was adorned, as no other civilization had been before or has been since, by Plato and Aristotle, by Æschylus and Euripides, by Pindar and Anacreon, by Phidias and by Praxiteles in philosophy and art. When the full realization of the glory of Greece is borne in upon us we no longer wonder at the remoteness of Hippocratic medicine from the charms and the incantations of Malay Magic and African ju-ju.

Elsewhere I trust I shall have an opportunity of tracing back from Hippocrates through Empedocles and Alcmæon some of the primitive traits recognizable in the fragments of the nature philosophers in connection with the earlier thought to be found in the Zend Avesta and the Rig Veda and even in Homer. To a certain extent these, especially the Zoroastrian and the Hindu Epics, are stepping stones back along the path to the Papyros Ebers and the Poem of Gilgamesh, but with these we need not here concern ourselves.

I wish here to dwell a little upon the assertion frequently made by many more recondite authors, but most popularly set forth in the attractive works of Leaf and Mahaffy and Murray and the many essays of other facile writers on Greek archeology, that there is little magic in Homer, scarcely anything in the Iliad at least. In the previous essay alluded to I have pointed out that we understand the ancient Greek because a part of his blood or at least his culture had come down to us from the western and northern slopes of the Alps before modern research studied it in the remains of ancient Greece. His methods of thought, his poetry and his dramatic art are familiar to us on this account, but we look down the paths of the black race, so intimately in touch with the civilization of the Mediterranean peoples before the first millennium B.C., and they are dark to us. Neither the black magic nor the white magic of the black man appeals to us at all as art in poetry or as logical in philosophy.

As we read the Homeric poems, possibly taking shape from the traditions of the people at a date ranging from the ninth or tenth to the seventh century before our era, we find very little indeed which we can assimilate with Oriental magic, the magic of the Malay or the African in his native jungles. We can find some explanation of its absence in the consideration that while the Iliad deals professedly with events which modern archeology places at least as early as the beginning of the first millennium B.C., they manifestly could only be expected to reveal those ideas and ideals, customs and manners and ways of thought familiar to the stage of culture in which they were written, extending well into a period of civilization in the Mediterranean basin, which was far removed, whatever its origin, from that of primitive man. Nevertheless, we have every reason to believe that at some period of the Hellenic culture there must have existed a state of art and thought which might fairly come within the definition of primitive. That this stage of social evolution antedated the first millennium B.C. might easily account for the absence of magic in Homer as it does in Hippocrates, but, so far as I have been able to remark, archeological investigation reveals plenty of primitive magic in Greece later than the date of the Trojan War.

There is, however, an argument which the attentive reader of the Iliad and the Odyssey may gain from the poems themselves. All critics bear out the statements, frequently made by philologists and antiquarians, that the Odyssey is of a later authorship than the Iliad, perhaps two or three hundred years

later. Now, it is precisely in the Odyssey that we are able to take notice of traces of magic to which modern ethnologists and archeologists have for many years constantly drawn attention. According to Abbott,[1] speaking of the Epic Cycle, the whole series of the Trojan poems, including the *Iliad* and *Odyssey*, is as follows:

1. The *Cypria*, of which the authorship is doubtful. Some considered it the work of Stasinus of Cyprus; others attributed it to Hegesias, or Hegesinus, of Salamis in Cyprus; others, again to Homer.
2. The *Iliad.*
3. The *Æthiopia*, by Arctinus of Miletus.
4. The *Little Iliad*, by Lesches of Mitylene.
5. The *Capture of Ilium*, by Arctinus of Miletus.
6. The *Nosti*, by Agias of Trœzen.
7. The *Odyssey.*
8. The *Telegonia*, by Eugammon of Cyrene.

In this series each poem takes up the story where the preceding poem ends. The same incidents are not repeated in any two of them, with some slight exceptions. . . . From the nature and construction of the Cyclic poems we were inclined to draw the inference that they were composed after the *Iliad* and *Odyssey*, and our conclusion is confirmed by what we know of the incidents recorded in them.

The great German critic Wolff made the assertion it has been difficult to refute that no texts of Homer or the Epic Cycle with which we are familiar existed before Alexandrian times.

Miss Harrison[2] perhaps makes use of her own notes when

The ghosts in the Nekuia of the *Odyssey* "drink the black blood" and thereby renew their life; but in ceremonies of purification they demand polluted water, the "offscourings," and why? The reason is clear. The victim is a surrogate for the polluted suppliant, the blood is put upon him that he may be identified with the victim, the ghost is deceived and placated.

She also draws attention to the passage in Hecuba of Euripides in regard to a matter which has its own interests for us. she says that

In the Hecuba of Euripides, Neoptolemos takes Polyxena by the hand and leads her to the top of the mound, pours libations to his father, praying him to accept the "soothing draughts," and then cries:

Come thou and drink the maiden's blood
Black and unmixed.

I can not pretend to say that the thought here can be anything but the assumption that Achilles' ghost may absorb

[1] Abbott, Evelyn, "History of Greece," New York, G. P. Putnam's Sons, 1888, pt. 1.

[2] Harrison, Jane Ellen, "Prolegomena to the Study of Greek Religion," Cambridge Univ. Press, 1903.

enough of the vital energy to allow him to go comfortably to join the shades below—a journey which in life he had no taste for, saying he would rather be the humblest slave on earth than associate with such unsubstantial company. Nevertheless, though it may have no meaning of sympathetic magic it is easy to see that the "blood is the life." It was not only human blood that was grateful to the ghosts. Odysseus in the Odyssey (XI., 25–50) says, according to the translation of Butcher and Lang,

> when I had besought the tribes of the dead with vows and prayers, I took the sheep and cut their throats over the trench, and the dark blood flowed forth, and lo, the spirits of the dead that be departed gathered there from out of Erebus. Brides and youths unwed, and old men of many and evil days, and tender maidens with grief yet fresh at heart; and many there were, wounded with bronze-shod spears, men slain in fight with their bloody mail about them. And these many ghosts flocked together from every side about the trench with a wondrous cry,

but he would not let them approach. In the Odyssey there is no sacrifice as in the Iliad of young men and maids. Human sacrifices, I think, can hardly be demonstrated always to be associated with or to be a relic of cannibalism, but since the latter practise is only of secondary interest we may turn to that form of it which was associated with homeopathic magic, the predecessor in human thought of the doctrines of Hahnemann. It is not only savage vengeance which Achilles breathes forth as he sees Hector, his prostrate foe, gasping at his feet—it is not only of his friend Patroclus, who fell by Hector's hand, that he thinks, it is ardent admiration for Hector's virtues which he supposes can be thus absorbed. Chapman's translation[3] runs thus:

> I would to God that any rage would let me eat thee raw,
> Slic't into pieces, so beyond the right of any law
> I taste thy merits!

This, though in the Iliad, is primitive enough. This is an indiscriminate appetite for all the virtues, but we can easily find indications that the passions have different seats. "Life," for which we can nearly always substitute "soul" as the conceptions if not identical are usually confused, we easily find in the blood.

While it is necessary to differentiate the historical, the archeological Troy from Homeric Troy, chiefly we are concerned with Homer, or rather with a number of Homers traveling up and down the littoral of Asia Minor for two or three

[3] Chapman, George, "The Iliads of Homer," tr. according to the Greek, by George Chapman.

hundred years after the catastrophe at Troy. So far as we can make out, most of the six or more cities, which were erected at different widely separated epochs on the site of Priam's city, were built there for—not to use a harsh word—commercial purposes—to levy toll on the merchandise which could not get through the rushing tide of the Bosphorus. Anger naturally arose among the people who would have liked to pass their mule trains overland free of tax, so successive cities rose and fell where Schliemann only looked for the one Homer wrote about. Now to suppose that such a center for all the roaring trade of the ancient civilizations, with the Black Sea outskirts of the Ægean, knew nothing of Babylonian magic is not reasonable. It was a cosmopolitan city even on Homer's showing. Diverse tribes were here allies. Memnon, a black man of the plains, married a light-haired woman from the mountains and led a dusky contingent to Troy. Hecuba, Priam's queen, was Phrygian. A piece of jade from far-away China was one of the things found in the ruins, etc. The latter perhaps is the most suggestive, because it is best authenticated. We might discard half the myths that point to the political status of ancient Troy, as archeologists now conceive it and there would still be left a respectable number. The persistence of the repetitions of city building on that site looking out over the Hellespont at the baffled vessels trying to stem the current which has upset the calculations of the master pilots on the super dreadnoughts of our day, presses for the obvious interpretation. That stone which only China can furnish speaks volumes.

> At Troy there are the remains of no less than six cities one above the other. There was a great city there in 2000 B.C., the second of the series. Even in the second city there was discovered a fragment of white nephrite, a rare stone not found anywhere nearer than China, and testifying to the distance which trade could travel by slow and unconscious routes in early times.[4]

So if Homer was ignorant of Babylonian magic or even of Malay magic it is because these particular varieties did not leave the caravans much, that wore the paths across Syria or the ships that passed by sea along her shore, not because oriental magic was not known to the real Trojans. There were things about Troy Homer did not know or that his audience were not interested in.

In the Iliad Homer wrote for those not interested in, and he himself there shows himself not much concerned with the

[4] Murray, Gilbert, "Rise of the Greek Epic," Oxford, Clarendon Press, 1911.

black man's magic, except as it concerned drugs. It would seem, however, if they had their knowledge of drugs from Egypt, they must have had to take with them much of the magic which rendered them efficacious, but Nestor in the Iliad said he had met in his youth Agamede and she, though not an Egyptian, "knew all drugs that the world nourisheth" (XI., 739). We may be privileged to doubt this, but we can see in the verse at least the indication that woman among the primitive Greeks took as naturally to herbs as she did among the hardy frontiers men in our early times. In the Odyssey, however, we find the fair Helen mixing a potion for Telemachus, in which some commentators see a hint of opium from Egypt, for

she cast a drug into the wine whereof they drank, a drug to lull all pain and anger, and bring forgetfulness of every sorrow. Whoso should drink a draught thereof, when it is mingled in the bowl, on that day he would let no tear fall down his cheeks, not though his mother and his father died, not though men slew his brother or dear son with the sword before his face, and his own eyes beheld it. Medicines of such virtue and so helpful had the daughter of Zeus, which Polydamna, the wife of Thon, had given her, *a woman of Egypt,* where earth the grain-giver yields herbs in greatest plenty, many that are healing in the cup, and many baneful. There each man is a leech skilled beyond all human kind; yea, for they are of the race of Pæon. (Odyssey IV., 230.)[5]

Where Circe's enchanted isle was we do not know, but the metamorphoses of the friends of Odysseus into swine and the love philters make us think it may have been an appendage of some Oriental country. At least we can see in the incident the bent of mind of the Mediterranean race rather than northern transformations. Eurylochus tells him:

Thy company yonder in the hall of Circe are penned in the guise of swine, in their deep lairs abiding. Is it in hope to free them that thou art come hither? Nay, methinks, thou thyself shalt never return but remain there with the others. Come, then, I will redeem thee from thy distress, and bring deliverance. Lo, take this herb of virtue, and go to the dwelling of Circe, that it may keep from thy head the evil day. And I will tell thee all the magic sleight of Circe. She will mix thee a potion and cast drugs into the mess; but not even so shall she be able to enchant thee; so helpful is this charmed herb that I shall give thee, and I will tell thee all. (Odyssey X., 275.) "Therewith the slayer of Argos gave me the plant that he had plucked from the ground, and he showed me the growth thereof. It was black at the root, but the flower was like to milk. Moly the gods call it, but it is hard for mortal men to dig; howbeit with the gods all things are possible."

She had so overcome his comrades with

"a mess of cheese and barley-meal and yellow honey with Pramnian wine,

[5] Butcher and Lang, "The Odyssey of Homer," done into English prose by S. H. Butcher, M.A., and A. Lang, M.A.

and mixed harmful drugs with the food to make them utterly forget their own country."

So the commentators again think of Egypt and opium and we may think at least in the Odyssey of Oriental magic. Indeed the story has been traced to Babylon,[6] but it is not necessary for us to believe it was anything but an indigenous story of the brown race.

The myth of the Harpies is told in connection with Phineus, the son of Agenor, one of the Homeric heroes, but though placed later than the Iliad, one of them is mentioned there (XVI., 150). I do not know as to the authenticity and the chronology of this passage, but in Hesiod and Theognis they appear. I think there can be no doubt they are lineal descendants of the creatures that carried the souls of Pharaoh's dead subjects around their tombs. They have only the incidental interest for us that we feel in the idea of the winged soul, the pneuma, the spiritual aspirations of man, the uplift of man to higher things, etc., but here they have an interest in bearing the impress of Mediterranean magic, perhaps combined with some northern myth, for Podarge, one of the three, was the dam of Achilles steeds sired by the West Wind. Other hints incidentally appear even in the Homeric epics of this intrusion of Mediterranean magic.

So far as we have gone on our own path it is evident that Keller[7] is justified in his conjecture that it is

with Phoenicians and their tales are probably to be associated the monsters of Homer: the Chimaera, a composite of lion, serpent, and goat, slain by the hero Bellerophon, the Gorgon's head, Scylla and Charybdis, the Sirens, etc., as well as the savage tribes so vaguely located about the world.

A small amount doubtless was imported magic, a certain amount the northmen brought with them, a certain amount they found indigenous in the Ægean area which may have been specific to certain localities, but we can scarcely go far wrong in believing that much the larger amount was a magic common to all primitive men at the stage of culture represented by Homer's Greeks. One of these traits we know is homeopathic or sympathetic magic, a very comprehensive division, yet so far as it is to be noted in affiliation with medicine it is scarcely to be found. We have seen Achilles desiring to eat Hector's flesh in order to get the virtues of his foe, but it is in the story of Telephus, which seems to have been preserved chiefly by Strabo, we get the most perfect exemplification of it. Euripides wrote

[6] "Encyclopædia Brittanica," Article —, "Circe," 11th ed.

[7] Keller, Albert Galloway, "Homeric Society," Longman, Green & Co., New York, 1913.

a play from the legend which had been lost. Plutarch[8] ("Morals," Vol. I., 289), Pliny[9] (XXXIV., 15) and Cicero[10] (Pro L. Flacco C., 29) and Pausanias[11] all refer to it. He married one of Priam's daughters, but he does not appear in any of the texts of the Homeric poems which have come down to us. He was severely wounded by Achilles and finally on the advice of an oracle came to Greece and presented himself to Achilles, who healed him by applying to the wound scrapings of the spear with which the wound had been inflicted. Presumably the legend grew out of the Homeric poems by the influence of a magic which it is hard to believe was not prevalent in Homeric medicine, and Grote[12] remarks that Strabo pays little attention to any portion of the Trojan war not found in the Homeric poems proper, and appears not to have read Arktinus, but he may have derived it from some equally ancient author. At any rate, even in the Roman development of Greek medicine it was a spur to homeopathic practise. Philostratus[13] tells how Apollonius cured a boy from a mad dog's bite, by sending the dog into the river and so curing it, whereon the bitten boy also recovered. "He said: 'The soul of Telephus of Mysia has been transferred into this boy, and the Fates impose the same things upon him as upon Telephus.'"

We are thrown therefore by the internal evidence of the poems themselves on the assumption that the author of the Iliad wrote in an atmosphere appreciably different from that of the author of the Odyssey. Quite independent of this internal evidence is the view that as northern blood poured into the Mediterranean area and gave it, at some date before the rise of the highest culture in Greece, a hue derived from another clime, cosmic influences, including that of disease, was at once at work to tap this foreign stream and finally to banish it through its lack of adaptation to the environment. Gradually the Northman died out and the Mediterranean race and its culture, at first submerged by the invasion, came again into its own. The date of the fourteenth century B.C. finds Egyptian influence still dominant on the mainland of Greece, or rather

[8] Plutarch, "How to Profit by our Enemies," Morals: Tr. from the Greek by Wm. W. Goodwin, 1820, Vol. 1, 289.

[9] Plinii, C., "Secundi: Naturales Historiæ," Lib. 11, XXXVII., Sect. 70, Silig, p. 300.

[10] Cicero, "De Natura deorum," III., 22. Teubner, 1890, pt. 4, Vol. 2.

[11] Pausanias, "Description of Greece," tr. by J. G. Frazer, London, Macmillan & Co., 1898.

[12] Grote, George, "History of Greece," Part 2, Ch. 15.

[13] Philostratus, "Flavius: The Life of Apollonius of Tyana," tr. by F. C. Conybeare, Vol. 2, Bk. 6, p. 143, London, Wm. Henilmann, 1912.

we are to suppose that it was more properly an Ægean than a strictly Egyptian culture. Sir Arthur Evans[14] of late has shown himself more and more inclined to limit the antiquity of the Northmen in the Ægean to some such epoch, for it is not the yellow-haired men but the brown-complexioned race, or the red men with high artistic capacities which are shown in the wall pictures, and he intimates that this artistic temperament was due to the blood of the Mediterranean race which finally predominated in the Ægean. The light-skinned people evidently came in and conquered in battle, but in the long run the race which had the traditions of African magic in its heredity came to the surface. "It is true that the problem would be much simplified if we could accept the conclusion that the representatives of the earlier Minoan civilization in Crete and of its Mycenæan outgrowth on the mainland were themselves of Hellenic stock." There is nothing which now seems improbable much less impossible in this commonly accepted view, but it lacks desirable confirmation.

> Doubtless some of these elements, notably in Crete, were absorbed by later Greek cult, but their characteristic form has nothing to do with the traditions of primitive Aryan religion. They are essentially non-Hellenic.

The period during which these Northmen were dominant begins according to Evans not earlier than the twelfth century and even in Hesiod's Theogony, five hundred years later, we find the trace of Set, Horus and Osiris in the spirit if not in the literal similarity of the myths. There is, it must be confessed, considerable ground for Evans' remark that "in the end, though the language was Greek, the physical characteristic of the later Hellenes prove that the old Mediterranean element showed the greater vitality." It was the brown race largely tinctured with the ideas of the African and the Asiatic. Enough has now been said to begin the attempt at the differentiation of the white man's magic from that of the brown man and the black man, the yellow man and the red man.

When we find the African chief soliciting the aid of invisible powers by hanging various articles on a blasted tree trunk or muttering words we do not understand to his block of wood or pieces of stone, we say this is magic. When we see in a Greek façade figures pleasing to our eyes grouped in what is to us artistic fashion, around a graceful altar from which the smoke of slaughtered goats ascends to heaven with that of the faggots of the fire, we say this is *art*.

[14] Evans, Arthur J., "The Minoan and Mycenæan Element in Helenic Life," *Journal of Hellenic Studies*, 1912, Vol. 32, pp. 277, 287.

When the African chief's medicine man tells him of the strange creature with horns and great round red eyes which his incantations have raised from the river's mud, we say this is magic, but when we read of the gray-eyed Athena plucking one of her heroes by the sleeve or by the hair invisible to all eyes but his, we say this is poetry, and when the details of hair and garment folds, of blowing winds and clouds in the sky are sketched for us, we say this is realism. Now I do not know what the evolved African chief or the Malay prince might say it is, with only his social heredity behind him, but I suspect he would say, why *this* is magic. Now I imagine something of this kind of subjectivity troubles our Homer critics. They can not shake off from themselves their social heredity. The various epiphanies of gods and goddesses on the battle field or in council have their "magic" for us, but we usually say "charm" and with the connotation of the two words we should set ourselves right. When Athena brushes aside like troublesome flies, the spears and arrows aimed at her protégé, we don't think at all of negro "magic" but of the "*charm*" of the white man's poet. Of course I might continue indefinitely thus to outline from the incidents in the Homeric poems illustrations of the reason I conceive why the northman critic finds so little magic in the northman poet's lines. This might be interesting but it would be exhaustive of space, and the chief thing for us in the lesson I am endeavoring to shadow forth is that it *was* northern magic, it *was* a new race coming in and remaining undefiled by southern magic for awhile that makes the northern critic, unable to pull himself up by his boot straps, unable to see the magic of his ancestor. There is some magic which we recognize as such in the Iliad and much more in the Odyssey and were we to add to it the magic we do not recognize on account of its "charm" the balance sheet between the African or Malay ledger and that of the Scythian from beyond the Danube would not show great discrepancy in the totals.

If there is a flaw in this argument, and I suppose there must be many of them, it is as to medical magic. Where are the incantations and the invocations, the beating of the tom-tom, the swinging of censers and the general chase after the soul and the flight from the disease devils and demons of Babylonia and Malaysia, the witches of the Congo and the Nile? There are not many of them in the Iliad and the Odyssey does not swarm with them as do the Zend Avesta and the Atharva Veda. But the malicious northern demons of disease are not there either and it really seems as though the argument I have adduced, if

it is worth anything at all, is applicable rather to magic in general than to medical magic. To this the answer is that neither the Iliad nor the Odyssey is a hospital history book nor the records of the health office, both phenomena of a static common wealth when we find them on our book shelves. These poems are annals of war and the itinerary of an adventurous traveller, full of wiles and lies but not interested even in surgery beyond wounds by sea and land and the occasional pestilence which halts the march of armies and is the stoled priest's business anyhow. The Atharva Veda and the Zend Avesta are the priests' own books, the Iliad and the Odyssey are those of the warrior and the soldier of fortune.

We may perhaps see in the Iliad in the sacrifice of horses attributed to the Trojans by Achilles (XXI., 131), a custom Xerxes followed when he passed the Nine Ways on his invasion to Greece as told by Herodotus (VII., 112), the same sacrifice being repeated by Mithridates and Sextus Pompeius,[15] but we may conjecture this was a custom the Northmen, including the Aryans, acquired before they entered the basin of the Mediterranean.

To the attentive reader of the Rig Veda which is claimed as more distinctly Aryan in origin and feeling it, like the Iliad, will seem to hold little we call magic and much we call charm or poetry. The Atharva Veda, a much later composition, is full of magic. In the argument as I have presented it for the Greek poems, the Vedic hymns would furnish parallel evidence.

[15] Seymour, Thomas Day, "Life in the Homeric Age," New York, The Macmillan Co., 1914.

THE ORIGINS OF CIVILIZATION[1]

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THE UNIVERSITY OF CHICAGO

FROM THE OLD STONE AGE TO THE DAWN OF CIVILIZATION. III

SUCH forces gradually brought about the union of two states on the Nile: in the *north* a kingdom of the delta commonly known as Lower Egypt; and in the *south* a kingdom of the valley above the delta, which we usually call Upper Egypt. The kingdom of Upper Egypt was evidently the older. Side by side the two existed for centuries, each gaining its own traditions, symbols and insignia which survived in historic times for thousands of years. In early dynastic reliefs like Fig. 41, we see

FIG. 41. TRIUMPH OF A PHARAOH AT THE BEGINNING OF THE DYNASTIC AGE. On the right, the king wears the white crown of Upper Egypt; on the left (top scene, left end) he wears the spiral-crowned diadem of Lower Egypt. Relief scenes on a magnificent ceremonial palette of slate. (From Quibell, "Hierakonpolis.")

the tall white crown worn by the prehistoric kings of Upper Egypt, and also the curious spiral-crowned red diadem which regularly distinguished the King of Lower Egypt. In a prehistoric struggle which must have gone on for generations, the king of Upper Egypt, he of the tall white crown, conquered his

northern rival of Lower Egypt, him of the curious red crown, and united Egypt under one sovereignty. Thus probably not more than a century after the middle of the fourth millennium B.C., emerged the first great state in history. In commemoration of his double sovereignty over the two prehistoric kingdoms, the Pharaoh, as we may begin to call him, assumed and wore the crowns of both states, as we see this king here doing on two different occasions. It is interesting to find him still wearing the symbol of his hunting ancestry—the tail of a wild animal appended to his girdle behind.

Such monuments as these show us how the prehistoric Egyptian system of picture signs was developing into phonetic writing. The victory of this king over the enemy symbolized by this single adversary whom he is shown dispatching (Fig. 41, right-hand relief), is commemorated in an archaic pictographic group over the head of the captive. The falcon (here with a human arm) is an enormously old symbol of the prehistoric ruler of upper Egypt. Knowing this, we easily read the group; for it will be noticed that the falcon grasps a rope by which he leads a captive suggested by a human head with the rope fastened to the mouth. This head rises out of a stretch of level ground out of which are growing six lotus leaves on tall stems each the symbol for 1000. Just below is a single barbed harpoon, and a small rectangle filled with wavy lines of water, meaning a pool or lake. The meaning of the whole is clear: "The Falcon King has led captive 6,000 men of the Land of the Harpoon Lake." The further process by which these purely picture signs became phonetic, furnishing the earliest known system of phonetic writing, is now fairly clear to us, but space will not permit its discussion here. It should be mentioned, however, that before 3000 B.C. this system of Egyptian writing developed a complete series of consonantal alphabetic signs, and there is now no reason to doubt that the Phœnician alphabet, and hence likewise our own, have descended from the picture writing of Egypt which we have just read. This question will be taken up more fully in discussing the Phœnicians.

It is of importance at this point to remember that the exclusively Nilotic origin of Egyptian writing is easily demonstrable. In view of this fact it is quite inexplicable that there should have been a wide-spread impression that it was of Asiatic origin. In the first place our oldest examples of Egyptian writing are older than the earliest known writing of Asia. Furthermore Egyptian writing is a veritable zoological and botanical garden of fauna and flora unmistakably Nilotic, while it includes also an extensive museum of implements, ap-

pliances, weapons, clothing, adornments, buildings, etc., peculiar to the Nile valley. Only lack of acquaintance with the material background of Egyptian life, and a failure to study carefully the content of the Egyptian sign lists, can account for the totally groundles assertion of the Asiatic origin of Egyptian writing by Hommel and de Morgan, which has unfortunately found its way into many current books. As his writing developed, the Egyptian at the same time devised the earliest known paper, which he succeeded in making from the papyrus reed

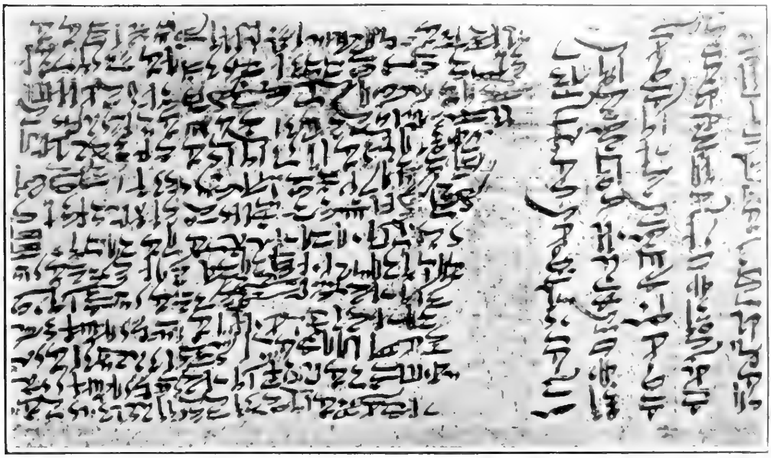


FIG. 42. SPECIMEN OF EGYPTIAN PAPYRUS PAPER, CONTAINING PART OF A TALE WRITTEN NEARLY 2000 B.C. Now in the Berlin Museum.

(*Cyperus papyrus*), a plant which grew very plentifully in the Nile marshes (Fig. 42). It has especial interest for us, because it was the first paper used by Europe, and as we shall see, this paper brought to Europe an alphabet which had grown up out of the system of Egyptian hieroglyphic of which we have just been speaking.

Thus emerged the first great organization of men, efficient in the possession of a system of written records and communication, and stably founded on a basis of agriculture and cattle breeding, prepared to exploit to the full the possession of metal tools. It was now that the kingship proved invaluable in furnishing the powerful organization for mining on a large scale which private initiative could not have furnished. The source of copper was in the Peninsula of Sinai.

Berthelot has remarked[20] how interesting it is, that probably at the beginning of the exploitation of these mines of

[20] "Sur les mines de cuivre du Sinai," *Comptes rendus de l'Académie des Sciences*, 19 Aug., 1896.

FIG. 44. ONE OF THE EARLY COPPER MINES IN SINAI WORKED BY THE ANCIENT EGYPTIANS. (Photograph by Petrie.)

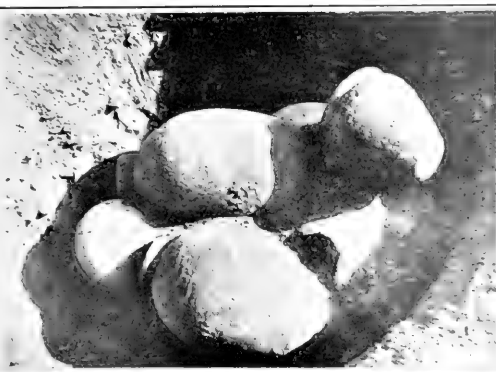
Sinai, that is over six thousand years ago, by an empiricism the origin of which is easy to conceive, man had already gained the processes for smelting metal, which have been followed ever since even down into our own day. Only recently have the metallurgical chemists succeeded in devising processes more successful and efficient than those which were first devised in Sinai over six thousand years ago.

This remark of Berthelot's justifies us in picturing the experience of some wandering Egyptian back in the fifth millennium B.C. as he banked his fire with pieces of copper ore which happened to be lying about his camp—part of the talus and detritus which encumbers the base of the cliffs in the lonely valleys of Sinai. As these natural fragments were exposed to the fire, the charcoal of the wood blaze, together with the heat, reduced a portion of the ore, and we can easily imagine how the attention of the wanderer would be attracted by a glittering globule of the liberated metal as it rolled out among the ashes.

The new age of mankind born on that memorable day was beginning to enter on its birthright, when centuries later the Egyptian monarchy emerged in the middle of the fourth millennium B.C. The metal, which the first Egyptian who possessed it had gained by accident, was now to be won systematically and on a relatively large scale, as only the sovereign could do in that distant age, when individual initiative was unequal to

the task. In Fig. 44 we see one of the ancient Egyptian mines in Sinai visible high up on the right. Though this particular example is not one of the earliest, these mines of Sinaitic Maghara are the oldest known mines in the world. Below the mine on a slight elevation at the foot of the slope we see the stone huts of the miners. A protective wall extends transversely across the valley. Here lived a little colony of miners. Plentiful evidences of their work are still scattered about the place. Under the floor of the hut they concealed the pottery canteen with which they carried on their rough-and-ready housekeeping, and there Petrie found it in his investigation of the place (Fig. 45). Their copper tools have likewise been found covered by rubbish (Fig. 46). The heavy stone picks which they still employed in getting out the ore, have likewise been found on the spot (Fig. 47).

The interiors of the mines themselves are very instructive. The action of the copper tools on the wall of the drift can still be closely followed and exhaustively examined, even to deter-



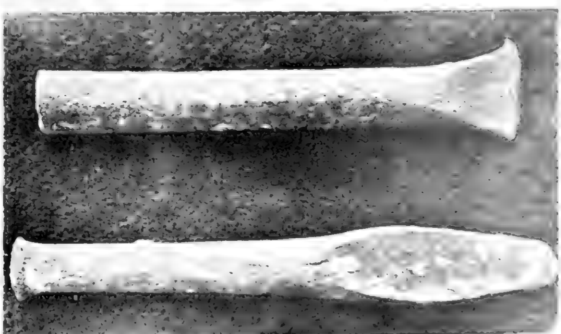


FIG. 45. POTTERY CANTEEN OF ANCIENT EGYPTIAN MINERS. Found buried under the floor of their hut in Sinai. (Maghara; photograph by Petrie.)
FIG. 46. COPPER CHISELS EMPLOYED BY ANCIENT EGYPTIAN MINERS IN SINAI. (Serabit; photograph by Petrie.)

FIG. 47. HEAVY STONE PICKS AND STONE DRILL-HEAD FOUND AT ANCIENT EGYPTIAN COPPER MINES IN SINAI. (Photograph by Petrie.)

mining the width of the chisel edge (Fig. 48). Though the mines are not usually large, and do not commonly exceed five feet in height, Fig. 49 shows a chamber of spacious dimensions. Space does not permit discussing the methods of freeing and taking out the ore; but we may glance at the evidences which disclose the smelting process. It is clear that smelting was often done directly at the mine. Petrie found the heavy stone pounders by means of which the ore was crushed (Fig. 50). Masses of slag have also been uncovered, and in Fig. 51 we see

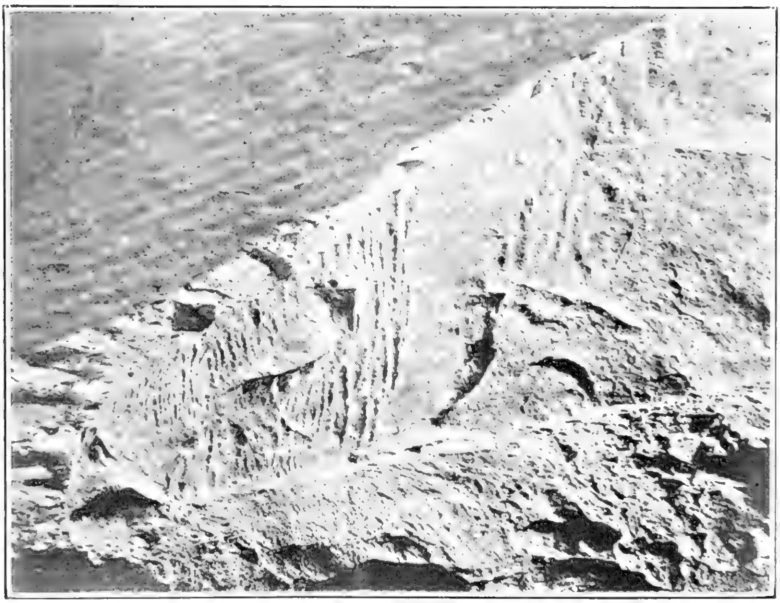


FIG. 48. WALL SHOWING STROKES OF COPPER CHISEL IN ANCIENT EGYPTIAN COPPER MINE IN SINAI. (Maghara; photograph by Petrie.)

a pottery crucible with large nozzle for pouring the molten metal into forms.[21]

The copper-bearing minerals which these earliest miners smelted were chiefly of three kinds: turquoise, containing only about three and a third per cent. of oxide of copper; a hydrosilicate of copper; and finally certain granites impregnated with carbonate and hydrosilicate of copper. These granites are also poor ore, but the hydrosilicate is sometimes very rich in copper.[22]

FIG. 49. INTERIOR OF A LARGE COPPER MINE WORKED BY THE ANCIENT EGYPTIANS IN SINAI. (Serabît; photograph by Petrie.)

The decisive importance of these mines in Sinai is evident when we understand that they are definitely dated. For over two thousand years the Pharaohs exploited the Sinai copper regions and have left their records on the rocks around the mines to testify to the fact. These records begin in the thirty-fourth century and continue until the latter part of the twelfth century B.C. It is not a little impressive at the present day to see appearing on the rocks before us the figure of the first ruler of men who has put himself on record as having organized and sent forth his people to bring out of the earth the metallic re-

[21] The above discussion of the ancient mines of Sinai is much indebted to the text and photographs of Petrie, "Sinai."

[22] See Berthelot, *ibid.*

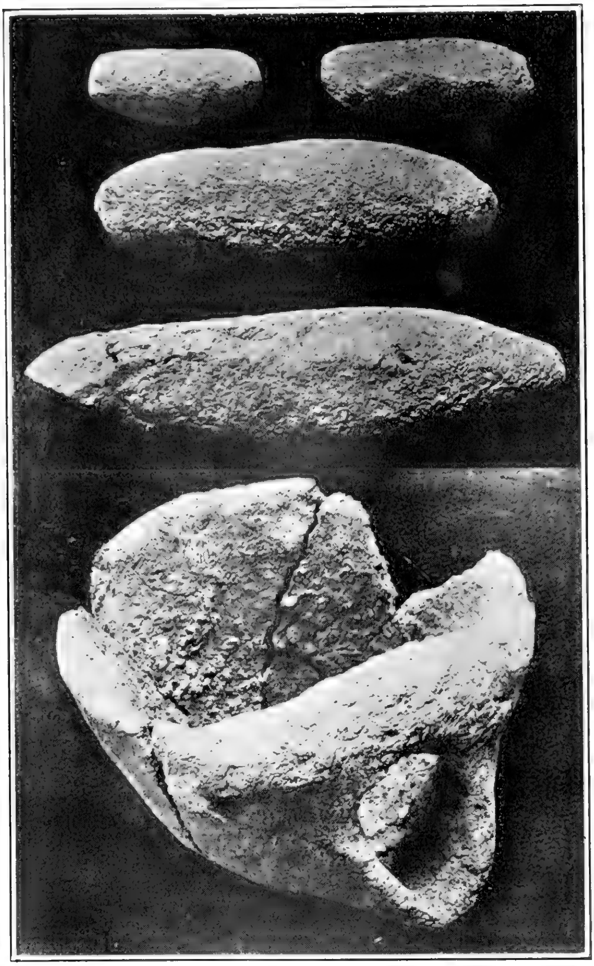


FIG. 50. STONE POUNDERS FOR CRUSHING COPPER ORE USED BY THE ANCIENT EGYPTIANS IN SINAI. (Photograph by Petrie.)

FIG. 51. POTTERY CRUCIBLE WITH NOZZLE FOR POURING MOLTEN COPPER INTO FORMS. Found at the ancient copper mines in Sinai. (Serabît; photograph by Petrie.)

sources without which man could no longer carry on a great state (Fig. 52).

As we approach we are standing in the presence of the earliest known historical monument. Carved with rugged and archaic simplicity, the figure of this earliest royal miner rises before us in heroic proportions. Here is the earliest sovereign to follow economic dictates and to march into a neighboring continent to seize by sole right of might the mineral wealth which his people needed. Depicted in the symbolic ceremony of crushing the Bedwi chief of the district, to signify the Egyptian Pharaoh's possession of the region, this king Semerkhet

thus published to the natives of western Asia his sovereignty over the world's earliest copper mines. He wears here the official crowns, the white and the red, which signify his supremacy over the Two Egypts, a supremacy which he had thus extended over neighboring Asia in the 34th century B.C. Thus the earliest known autocracy, seizing the mineral-bearing regions of Asia which it needed, some 5,300 years ago, began that long career of aggression based on economic grounds, which continuing ever since culminated in the seizure of the mineral wealth of northern France in August, 1914.

This record of Egyptian conquest in metallurgy, let it be noted, consists of inscriptional as well as sculptured elements. The name of the king in Egyptian hieroglyphics of unmistakable Nilotic origin, accompanies his figure, and it is well to remember that this mining record, made after Egypt had known of copper for over half a millenium, is nevertheless several centuries older than the oldest dated piece of copper known in Asia.

This earliest family of sovereigns ruling over a people of several millions was founded about 3400 B.C. by Menes, the first of the Pharaohs. His home was at Thinis, near Abydos in Upper Egypt, below the great bend where the river approaches most nearly to the Red Sea. We call the whole group the First Dynasty, and together with the second group, or second Dynasty, these early dynastic kings of Egypt were

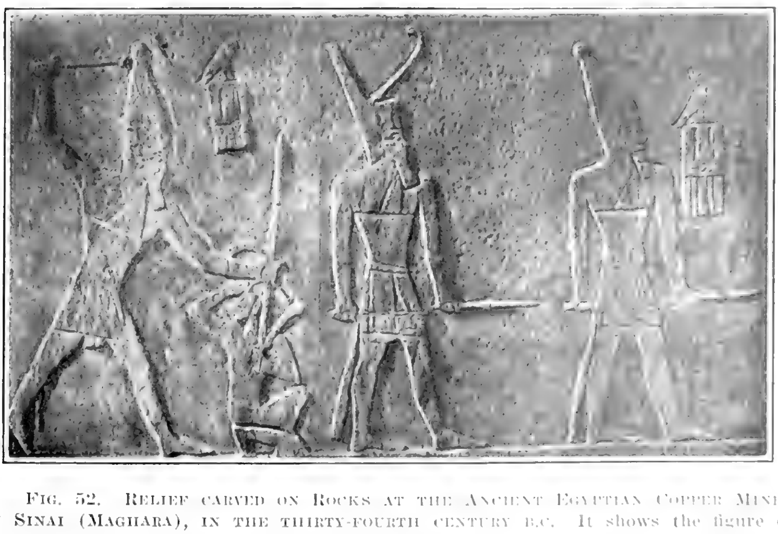


FIG. 52. RELIEF CARVED ON ROCKS AT THE ANCIENT EGYPTIAN COPPER MINES IN SINAI (MAGHARA), IN THE THIRTY-FOURTH CENTURY B.C. It shows the figure of the earliest known mining promoter, King Semer-khet of Egypt. At the left he smites a Bedwi chief of the region, while his other two portraits display him once with the crown of Upper and again with the crown of Lower Egypt. This is the oldest historical monument known, and the earliest such record of a foreign conquest on alien soil. (Photograph by Petrie.)

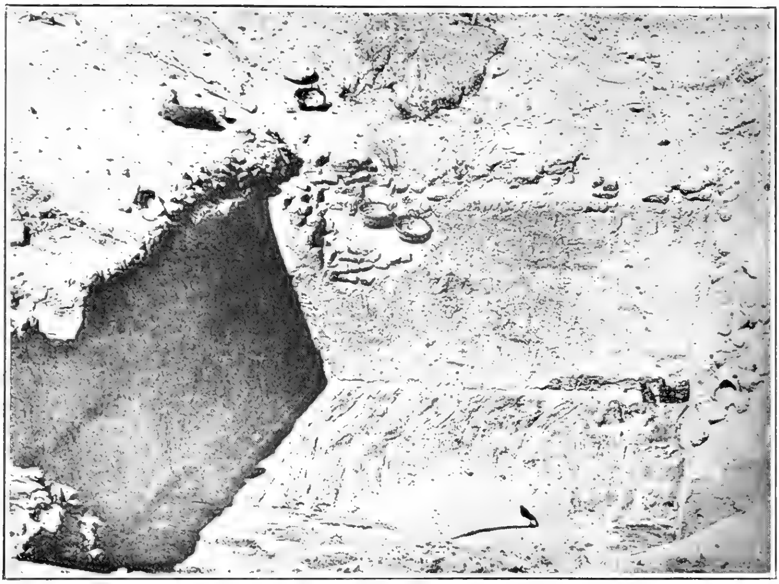


FIG. 54. BRICK-LINED TOMB CHAMBER OF ONE OF THE EARLY DYNASTIC KINGS (ABOUT 3400 TO 3000 B.C.) AT ABYDOS. (Photograph by Petrie.)

buried in the desert behind Abydos, where the wreckage of nine of their tombs still survives (Fig. 54). After Améli-neau's unsuccessful and destructive attempt to excavate these

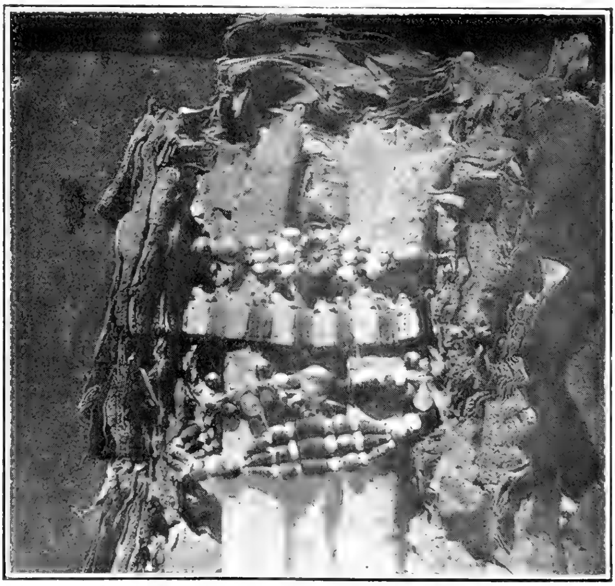


FIG. 55. FOUR BRACELETS OF GOLD AND PRECIOUS STONES, STILL ON THE ARM OF A ROYAL LADY. Found by Petrie in one of the early dynastic tombs of Abydos. (Photograph by Petrie.)

tombs, we owe the rescue of what was left, to Petrie's efforts. He was able to save enough of the palace furniture and other royal equipment placed in these tombs for the use of the royal dead in the hereafter, to disclose to us the remarkable progress of this earliest state in material life, especially in arts, industries and craftsmanship, during the last four centuries of the fourth millennium B.C., that is about 3400 to 3000 B.C.

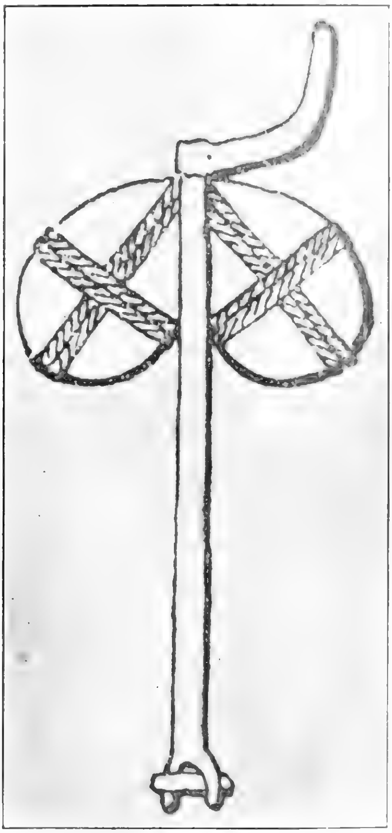


FIG. 56. EGYPTIAN CRANK DRILL INVENTED IN THE EARLY DYNASTIC PERIOD (ABOUT 3400 TO 3000 B.C.), THE EARLIEST KNOWN MACHINE. (Drawn by Borchardt from a hieroglyph.)

The advance in industrial appliances of which the jewelry in Fig. 55 gives evidence, is illustrated by a very important device for drilling out stone vessels, which was invented in the early dynastic period (Fig. 56). It is elaborately drawn for us in hieroglyphic, in which it became the sign for "craftsman." It consists of a vertical shaft with a crank attached at the top, and forked at the base to receive a cutting edge in the form of a sharp stone. Just below the crank are attached two stone

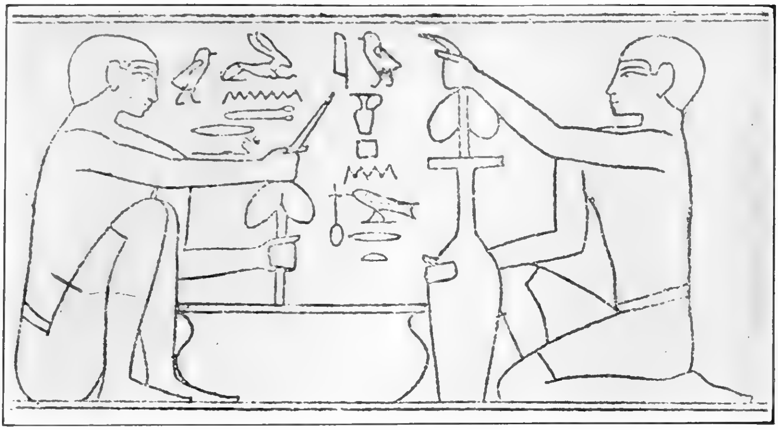


FIG. 57. EGYPTIAN CRAFTSMEN ENGAGED IN DRILLING OUT STONE VESSELS WITH THE CRANK DRILL SEEN IN FIG. 56. The scene is taken from a tomb relief. The hieroglyphs between the two workmen record their conversation. One says: "This is a very beautiful vase." The other responds: "It is indeed." (From de Morgan, "Recherches sur les origines de l'Égypte," I.)

weights, like the two balls of a steam governor. These of course serve as a fly wheel to keep the shaft revolving. Here is the earliest machine which can fairly be called such. It displays the earliest known crank or crank-driven shaft. The result was superb stone vessels and the development of a new and highly refined craft (Fig. 57).

Stimulated perhaps by his rival who was producing such beautiful stone vases, the potter at this time also made a great advance in his ancient art. For ages, since his ancestors of the lower alluvium, who already lay buried many feet below the potter's yard, he had laboriously built up his vessels by hand. But now he perfected what was perhaps at first merely a revolving bench, till it emerged as the familiar potter's wheel, the ancestor of the lathe, upon which his clay vessels were now turned.

Thus before 3000 B.C. Egyptian craftsmen devised two revolving machines, involving the essential principle of the wheel, with a *vertical* axis; but the wheel as a *burden-bearing device* with a *horizontal* axis (unless as employed in the pulley block?) did not arise in Egypt. It was first used in Asia. On the basis of these devices, and a long list of metal tools highly specialized, there arose a large group of sharply differentiated crafts, among which was the important art of glaze-making, the forerunner of the first production of glass. All these crafts were carried on by the first great body of *industrial* population known in history. They were in existence before 3000 B.C.

The great African game preserve at the southeast corner of

the Mediterranean, which once supported only detached groups of hunters wandering through the jungle, had become a huge social laboratory, where these Stone Age hunters had been transformed first into plowmen and shepherds and then into handicraftsmen. In the course of this process civilization arose and gained a stable political basis in the thousand years between 4000 and 3000 B.C.

Thus supported upon an economic foundation of agriculture, animal husbandry and manufacturing industries, arose the first great state on the Mediterranean, indeed the first great state in the world, at a time when all the rest of mankind was still living in Stone Age barbarism. Such a stable fabric of organization, under the power of the old falcon chieftain, once ruler only of Upper Egypt, but now sole head of all the Egyptian people, had shifted man from a struggle with exclusively *natural* forces, into a new arena where he must thenceforth contend with *social* forces, and out of his crucible of social struggle were to issue new values of a different order, like social justice, the value of right conduct, and hopes of happiness beyond the grave based upon worthy character—conceptions in which the Nile dwellers were as far in advance of the world about them as they were in their conquest of the material world.

This extraordinary forward movement of man before 3000 B.C. in the vicinity of the junction between the two continents, Africa and Eurasia, could not go on without important effects on the advance of man in Western Asia. It is evident that here too man had been pushing forward since Paleolithic times, and his ultimate progress in the whole region around the eastern end of the Mediterranean and down the Tigris-Euphrates valley was to have a profound influence on the career of man in the Mediterranean and thus upon the course of general human history.

The chronological relations of the cultures on the Nile and the Euphrates have not yet been definitely determined. Just as in the case of Egypt, so with regard to Babylonia, the excessively remote dates once current have been shown to be untenable. They have been given wide currency by de Morgan and others. De Morgan bases his conclusions upon two bodies of evidence. First the chronology once drawn from the written documents; and second his own excavations at Susa, the leading town in the old Elamite country on the east of Babylonia. Dr. King of the British Museum long ago discovered evidence which showed that the chronology drawn from the written documents which dated King Sargon of Akkad in the thirty-eighth century B.C. was impossible. De Morgan's distinguished

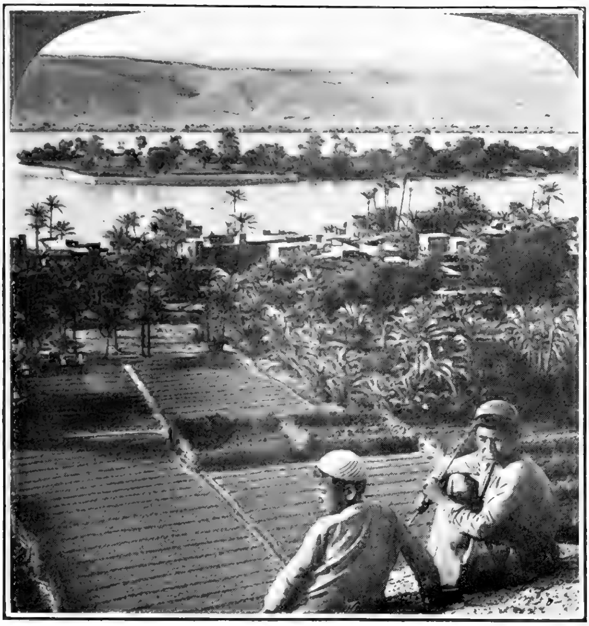


FIG. 60. THE RIVER TERRACES OF THE EUPHRATES, LOOKING EASTWARD ACROSS THE RIVER. About two hundred and fifty miles northwest of Babylon. (Copyright by Underwood & Underwood.)

countryman, Thureau-Dangin, has only in the last few months published a conclusive reconstruction, leaving nothing to be desired in its finality—a reconstruction which places Sargon well this side of 2800 and our earliest written documents of Babylonia hardly earlier than the thirty-first century B.C.

As to de Morgan's earliest periods at Susa, he dates them by their relative depth, that is by the amount of accumulated rubbish over them. Such rubbish produced by the detrition or violent destruction of sun-dried brick buildings, will of course accumulate at a rate variable from site to site and country to country, depending on a wide range of height of the buildings, widely differing thickness of the walls, the varying rapidity of detrition caused by the differing amount of rainfall and the uncertain number of the successive violent destructions. Following de Morgan, R. Pumpelly has made similar calculations for the age of the lower strata in his excavations of the ancient city of Anau in Turkestan. Among other data as a basis, he took the very slow accumulation of such rubbish in Egypt, without taking into consideration the difference in rainfall (Egypt having practically none), the difference in height of buildings and thickness of walls, and the politically sheltered situation of Upper Egyptian cities which exposed them to less

frequent destruction than the cities of Asia.[23] Such calculations have no value.

The development of civilized man on the lower Euphrates had undoubtedly been going on for ages before the date of his earliest surviving written documents (thirty-first century B.C.), but the age of that development has yet to be established; for unfortunately the prehistoric stages of Babylonian culture have not yet been recovered.

The river terraces of the Euphrates, such as we see in Fig. 60 overlooking a beautiful island, have not been investigated geologically, paleontologically or archeologically at all. It is evident that man dwelt between the Euphrates and the Mediterranean in Paleolithic times. His remains and his stone implements may therefore lie under and along these Euphrates terraces as they do along the Nile. They have indeed been found in Palestine and along the Phœnician coast, in caves, so stratified as to leave no doubt of their Paleolithic origin. From these early stages until the earliest written documents on the Babylonian alluvium (about thirty-first century B.C.), we have no evidence for the course of the development in western Asia.

It is, however, already perfectly clear that while the Nile valley made the earlier advance, and was the earliest home of civilization, there was reciprocal influence between the two early cultures on the Nile and the Euphrates. Thus the mace

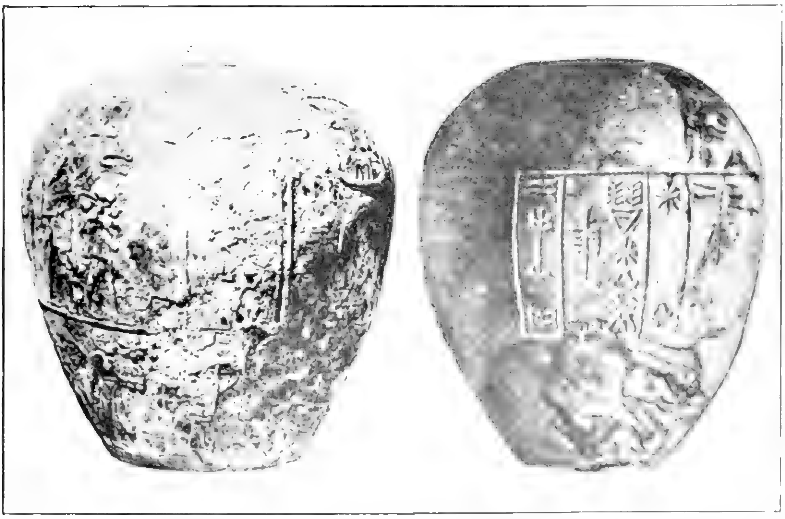


FIG. 61. EGYPTIAN AND BABYLONIAN MACE-HEADS OF THE SAME FORM.

[23] It may be added that Dr. Hubert Schmidt, the able archeologist attached to the Anau excavations, dated the oldest remains found there at about 2000 B.C.

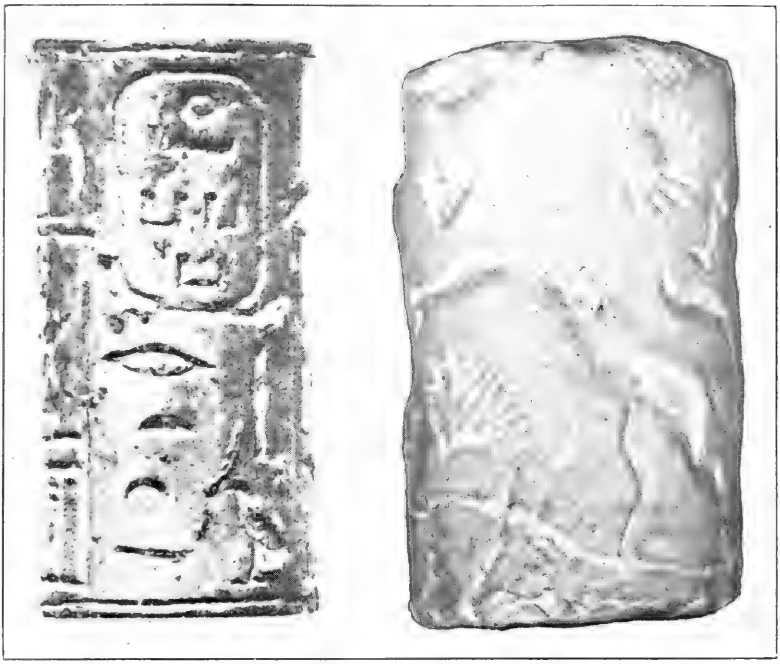


FIG. 62. EGYPTIAN AND BABYLONIAN CYLINDER SEALS OF THE SAME FORM.

head which we find in Egypt far back in the fourth millennium B.C. is also found along the Euphrates many centuries later (Fig. 61). Similarly the cylinder seal employed for sealing clay is found on the Nile centuries earlier than our earliest Babylonian example of it (Fig. 62). The decorative arrangement of balanced animal figures (Fig. 63), especially with a human figure in the middle, is found on the Nile well back

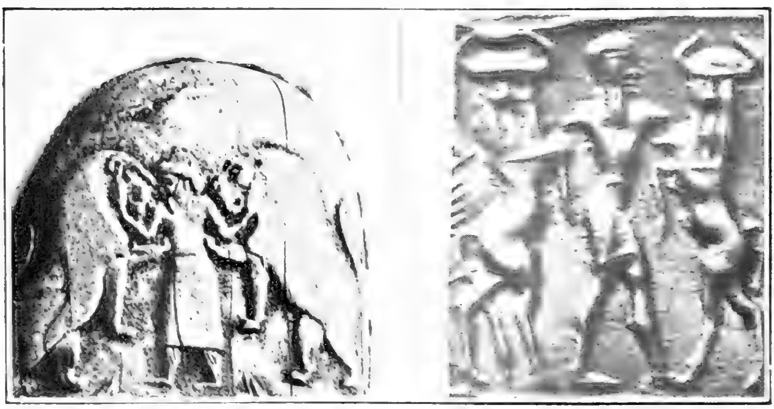


FIG. 63. EGYPTIAN AND BABYLONIAN DECORATIVE DESIGNS. Made up of animal figures balanced antithetically on either side of a human figure.

toward 4000 B.C., and our earliest examples in Babylonia cannot be dated earlier than the thirty-second century B.C. In such matters it should be remembered, however, that an inferior civilization often makes contributions to a superior culture. We have only to remember the source of tobacco, maize, potatoes and the like to illustrate this fact. There will, therefore, have been mutual exchange between the Nile and the Euphrates at a very remote date, and some of these parallels here exhibited may be examples of such mutual interchange.

This process created a great Egypto-Babylonian culture nucleus on both sides of the inter-continental bridge connecting Africa and Eurasia. It brought forth the earliest civilization in the thousand years between 4000 and 3000 B.C., while all the rest of the world continued in Stone Age barbarism or savagery. Then after 3000 B.C. began the diffusion of civilization from the Egypto-Babylonian culture center. The best illustration of what then took place is furnished by our own New World. In only two places on the globe have men advanced unaided from Stone Age barbarism to the possession of agriculture, metal and writing. One of these centers is that which we have been studying here in the Old World; the other is here in the New World.[24] Just as the Egypto-Babylonian culture center grew up at the junction between the two continents, Africa and Eurasia, as the oldest and the original center of civilization in the Old World, so here in the New World the oldest and original center of civilization likewise developed along and on each side of the inter-continental bridge. The far-reaching labors of a great group of Americanists have shown clearly that from this culture center in the inter-continental region of the Western Hemisphere a process of diffusion of civilization went on northward and southward into the two continents of the New World, and that process was still going on when the period of discovery and colonization began. That which we accept as a matter of course as we study the New World center, was obviously going on for thousands of years around the Old World center, although a provincially minded classicism has blinded the world to the facts. It remains for us in the next lecture, therefore, to follow the lines of culture diffusion, diverging from the Egypto-Babylonian group and stimulating Europe and inner Asia to rise from Stone Age barbarism to civilization.

[24] See the present writer's article, "The Place of the Near Orient in the Career of Man, and the Task of the American Orientalist" (presidential address before the American Oriental Society, in *Journ. of the Am. Or. Soc.*, June, 1919).

NATURAL DEATH AND THE DURATION OF LIFE

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I

THE efforts to prolong life have resulted in a diminution of the chances of premature death. Nations with adequately developed facilities for medical research and an efficient public health service have practically eliminated smallpox and typhoid, yellow fever and malaria, and have conquered rabies, diphtheria, tetanus, and cerebrospinal meningitis. If this development continues to receive the support it deserves, the time is bound to come when each human being can be guaranteed with a fair degree of probability a full duration of life. But why must we die?

The French encyclopedists of the eighteenth century defined life as that which resists death. What they meant by this definition was the fact that as soon as death sets in, the body begins to disintegrate. They argued correctly that the forces of disintegration were inherent in the living body but were held in check during life. Recent progress in physical chemistry permits us to state that the spontaneous disintegration of the body which sets in with death (at the proper temperature and proper degree of moisture) is a process of digestion, comparable to that which the meat we eat undergoes in our stomach and intestine. The essential feature of digestion is in this case the transformation of the solid meat into soluble products by two ferments, pepsin, which exists in the stomach, and trypsin, which exists in the intestine. The successive treatment of meat by the two ferments results in the breaking-up of the large insoluble molecules into the small soluble molecules of amino acids which are absorbed by the blood and carried to the cells of the body where they are utilized to build up new solid cell matter.

These two ferments, pepsin and trypsin, exist not only in the digestive organs, but in many, and possibly in all living cells, and the question arises, why they do not constantly digest and thus destroy our body while life lasts. A tentative answer

to this question has been given by Dernby, who has been able to show that the cooperation of both ferments is required in the same cell for the work of destruction, and that this cooperation of both ferments becomes possible only at a certain degree of acidity, which cannot be reached in the living body on account of the constant removal of acid through respiration and oxidation. When respiration ceases, the degree of acidity necessary for the digestive action of both ferments in the same cell is reached, leading to gradual digestion and liquefaction of the tissues which characterizes the disintegration of the dead body.

This is not the only cause of disintegration, since the dead body becomes also the prey of the destructive action of microorganisms from the air and in the intestine. During life these same microorganisms are powerless in their attack on the cells protected by a normal membrane, but after death this membrane is destroyed and the action of microorganisms can superimpose itself on that of digestion. It is also probable that the normal secretions of the mucous membranes during life have a protective effect.

Death, then, in a human being means the permanent cessation of respiration. We know that this result can be brought about by mechanical violence, by poison, and by disease, and, since nobody can escape all these agencies, doubts have arisen whether we do not all die from injury or disease, and whether such a thing as natural death really exists. If there were no natural death it should be possible to prolong life indefinitely if a complete protection against disease and accidents could be secured. It is impossible to make such an experiment in a human being, since our intestine and our respiratory tract can not be kept free from microorganisms. The problem has, however, been solved for certain insects. A Russian author, Bogdanow, invented a method of obtaining the common housefly free from all microorganisms, by putting the newly laid eggs for a number of minutes into a solution of bichloride of mercury of sufficient concentration. Most eggs were killed in the process, but some survived and these were free from microorganisms at their surface. By keeping the eggs on sterilized meat and in sterile flasks, the maggots leaving the egg could find their food and develop into flies. A French author, Guyénot, continuing the experiments on the fruit fly, raised 80 successive aseptic generations, and Northrop and the writer have raised thus far 87 aseptic successive generations of the

fruit fly on aseptic yeast. In these experiments all possibility of infection, all chances of accidental or violent death were excluded. To make sure that these flies are absolutely free from microorganisms, their dead bodies are transferred to culture media such as are used for the growth of bacteria. If a common fruit fly is put on such a culture medium, in 24 hours a rapid growth of microorganisms develops, while the culture medium on which our aseptic flies were put remained free from all growth for years (or rather permanently). Aseptic fruit flies, free from infectious disease and supplied with proper food will, therefore, not escape death. These experiments, then, indicate that higher organisms must die from internal causes even if all chance of infection and all accidents are excluded.

II

These aseptic flies served as a means for testing an idea concerning the duration of life which presented itself, namely, that old age and natural death are due either to the gradual production in the body of a sufficient quantity of harmful or toxic substances, or to the gradual destruction of substances in the body required to keep it in youthful vigor, or to both. On this basis the natural duration of life would be in reality the time required to complete a chemical reaction or a series of chemical reactions, resulting in the production of toxic compounds in a quantity sufficient to kill, or resulting in the destruction of necessary compounds. Metchnikoff had called attention to the fact that toxic substances were formed in the intestines under the influence of microorganisms. The intestine of aseptic flies is free from microorganisms, so that the source for the shortening of life pointed out by Metchnikoff need not be considered in this case. The toxic substances formed might be substances formed in one or several organs of the body during their normal activity. Modern physical chemistry furnishes the means of testing such an idea. The period of time required to complete a chemical reaction diminishes rapidly when the temperature is raised and increases rapidly when the temperature is lowered. Exeriments show that the time required for the completion of a chemical reaction is doubled or trebled when the temperature is lowered by 10° centigrade. This influence of temperature upon the rate of processes of nature seems to be typical for chemical reactions. If, therefore, the duration of life is the time required for the completion of certain chemical reactions in the body we might

expect that the duration of life will be doubled or trebled when we lower the temperature ten degrees centigrade. Such experiments can be carried out only in organisms where accidental death by infection is excluded and our aseptic fruit flies satisfied this condition. These experiments were made by Dr. Northrop and the writer, and consisted in putting a number of newly laid eggs of aseptic flies on an abundance of sterilized yeast (which is their natural food) in a flask plugged with cotton. These flasks were put into incubators the temperature of which was kept constant within 0.2 of a degree centigrade. The temperatures selected for the purpose were 10, 15, 20, 25, 27.5, and 30° C. It is not possible to go into the numerous precautions which it was necessary to take and the many technical difficulties involved in this investigation. The result of a large number of experiments was that the duration of life of such aseptic flies was a definite one for each temperature, which means that all the flies died at practically the same age when kept at the same temperature. Thus, for instance, the total average duration of life of such flies was 21.15 days at 30° C. The overwhelming majority died at that age, but a few died a little earlier and a few a little later. When the number of flies of a culture which die on successive days is plotted in terms of percentage of the original number of flies, we get that curve of death rates usually given in life insurance statistics. But this curve is very steep in our case owing to the fact that the majority of flies die at about the same time for a given constant temperature. The following table gives the average duration of life of the fly in days for different temperatures.

TABLE I

Temperature, °C.	Average Duration of Life of the Fly from Egg to Death, Days
30	21.15
25	38.5
20	54.3
15	123.9
10	$177.5 + x$

This table shows that the influence of temperature on the duration of life of the fly is the same as the influence of temperature on the velocity of a chemical reaction, inasmuch as a lowering of the temperature by ten degrees results in an increase in the duration of life by two or three hundred per cent., and the same figure would be obtained if we investigated the effect of temperature upon the time required to complete a chemical reaction. At 30° C. the flies live on an average 21.15

days and at 20° C. they will live on an average 54.3 days or a little over twice as long. At 25° they live 38.5 days and at 15° C. 123.9 days or about three times as long. The fruit fly is a tropical organism and 30° C. is not far from the optimal temperature. By lowering their temperature twenty degrees we prolong the duration of their life by nine hundred per cent. We cannot lower the temperature below 10° since the flies suffer in the chrysalid stage when the temperature becomes 10° or less. While these are thus far the only experiments on the duration of life of higher organisms carried out with the necessary scientific precaution, there are many casual observations mentioned in the literature which suggest that lowering the temperature prolongs the duration of life of lower animals in general.

The body temperature of a normal human being is constant, namely about 35.5° C. and this temperature remains the same in the tropics and in the arctic regions. Human beings and most mammals differ in this respect from insects whose temperature is as a rule practically that of their surroundings. If if were possible to reduce the temperature of human beings and if the influence of temperature on the duration of life were the same as that in the fruit fly, a reduction of our temperature from 37.5 to about 16° would lengthen the duration of our life to that of Methusaleh; and if we could keep the temperature of our blood permanently at 7.5° C., our average life would (on the same assumption) be lengthened from three score and ten to about 27 times that length, *i.e.*, to about nineteen hundred years. Unfortunately our body does not tolerate any considerable lowering of its temperature and if it did, life at so low a temperature would probably become very monotonous and uninteresting since in all probability sensations of pleasure as well as pain, of joy and of sadness, would be at a very low level.

The experiments on aseptic flies therefore lend support to the idea that the duration of our life is the time required for the completion of a chemical reaction or a series of chemical reactions. If these reactions consist in the gradual accumulation of harmful products in our body, or in the gradual destruction of substances required for a youthful condition, we understand why senile decay and death are the natural result of life.

III

Unicellular organisms, like bacteria, algæ or infusorians, seem to be immortal. They reach a certain size, divide into

two, each half growing again to full size and dividing again, and so on. In this case we may say that it is practically the same individual which continues to live in the successive generations. Small pieces of a cancerous tumor can be transplanted successfully to other individuals and these pieces grow again to a large size. This process can also be repeated indefinitely, and it is the same cancer cell which continues to live in these successive transplantations, as it is the same bacterium which continues to live in successive generations. In this way it has been shown that cancers in mice may outlive many times the natural life of a mouse, in fact they seem to live indefinitely. Cancer cells may therefore be called immortal as was pointed out by Leo Loeb many years ago.

It seems that this is true also for certain normal cells like connective tissue cells. Carrel has isolated connective tissue cells from the heart of a chick embryo and cultures of these cells living on the extracts from chick embryos have been kept alive now for seven years.

All this points to the idea that death is not inherent in the individual cell, but is only the fate of more complicated organisms in which different types of cells or tissues are dependent upon each other. In this case it seems to happen that one or certain types of cells produce a substance or substances which gradually become harmful to a vital organ like the respiratory center of the medulla, or that certain tissues consume or destroy substances which are needed for the life of some vital organ. The mischief of death of complex organisms may then be traced to the activity of a black sheep in the society of tissues and organs which constitute a complicated multicellular organism.

IV

While in human beings there is no sharp limit between youth and maturity, in many insects and amphibians this limit is marked by a sudden metamorphosis in the shape of their body. The frog hatches from the egg as a tadpole without legs and with a long tail. After a certain length of time legs begin to grow, the tail disappears, the form of the head and mouth change, the skin looks different, and the tadpole is transformed into a frog. It is possible that some of the changes underlying metamorphosis are due to changes in the circulation of the blood. Gudernatsch made the remarkable discovery that this metamorphosis, which in our climate usually occurs during the third or fourth month of the life of the tadpole, can be brought

about at will even in the youngest tadpoles, by feeding them with thyroid gland, no matter from which animal. By feeding very young tadpoles with this substance, frogs not larger than a fly could be produced. Allen added the observation that if a young tadpole is deprived of its thyroid gland, it is unable ever to become a frog; and that it remains a tadpole which can reach, however, a long life and continue to grow beyond the usual size of the tadpole. When, however, such superannuated tadpoles are fed with thyroid they promptly undergo metamorphosis. These observations cleared up an old biological puzzle. Salamanders also go through a metamorphosis which is, however, less striking than that of the tadpole of a frog. In the salamander the metamorphosis consists chiefly in the throwing off of the gills, and in changes in skin and tail. In Mexico a salamander occurs which through its whole life maintains its tadpole form, namely the axolotl. Attempts to induce the axolotl to metamorphose failed until after Gudernatsch's discovery an investigator fed the axolotl thyroid gland, and this brought about metamorphosis. The thyroid gland stores the traces of iodine taken up in our food and it seemed possible that the iodine contained in the thyroid was the active principle causing metamorphosis in tadpoles. This was confirmed by Swingle who succeeded in inducing metamorphosis in tadpoles by feeding them with traces of inorganic iodine. According to our present knowledge, the duration of the tadpole stage seems to be the time required to store the necessary amount of certain compounds, one of which contains iodine.

Insects, like the fruit fly, hatch from the egg as maggots which grow at the expense of the food they take up and which, at a certain age, metamorphose into a chrysalid; and from this chrysalid at a given time will rise the winged fly. Feeding of thyroid to the maggots of the fruit fly will not accelerate their metamorphosis, and we can not yet tell whether in this case metamorphosis is due to the accumulation or formation of a definite compound in the body, though this may well be the case. The idea presented itself whether the duration of the larval or maggot stage was not also determined by the temperature (provided the food supply was adequate). We measured, therefore, the influence of temperature upon the duration of the larval state in aseptic fruit flies—*i.e.*, from the time the egg was laid until the maggot was transformed into a chrysalid. The influence was practically identical with that of temperature on the total duration of life. Thus the larval period lasted 5.8 days at

25° C. and 17.8 days at 15° C., a ratio of about 1:3. The total duration of life of aseptic flies is 38.5 days at 25° and 123.9 days at 15° C., also a ratio of about 1:3. We are, therefore, justified in making the statement that the influence of temperature upon the duration of the larval period or the youth of aseptic flies is practically identical with the influence of temperature on the total duration of life.

Experiments by Uhlenhuth on the influence of temperature on metamorphosis in salamanders have shown that it is similar to that observed in flies. Salamanders kept at 25° metamorphosed when they were 11 weeks old, while salamanders kept at 15°, under otherwise identical conditions, metamorphosed when they were 22 weeks old. All these data suggest the possibility that the duration of life and the duration of the larval period or of youth are in reality times required for the completion of definite chemical reactions. The cessation of respiration leading to the termination of life and the alterations in circulation leading to metamorphosis or termination of youth are critical points; and it seems possible that these points are reached when a certain toxic substance is formed in adequate quantity in the body, or when a necessary substance is destroyed or sufficiently diminished in quantity, or when both conditions are fulfilled.

We can prolong or shorten the period of youth in amphibians not only by modifying the temperature but by withdrawing or offering the specific substance which causes metamorphosis, namely iodine or thyroid material. There is no end to the substances capable of hastening death. Shall we ever find a substance which will prolong the duration of life? At present we can neither deny nor affirm the possibility.

THE PROGRESS OF SCIENCE

THE PRINCIPLE OF RELATIVITY AND THE DEFLECTION OF LIGHT BY GRAVITATION

CABLE despatches from England report a joint meeting on November 6 of the Royal Society and the Royal Astronomical Society, at which Sir F. W. Dyson, the astronomer royal, and Dr. A. C. Crommelin, of the Royal Observatory at Greenwich, announced that an examination of the photographic plates taken during the solar eclipse of last May show a deflection of the rays of light from the stars in their passage past the sun that accords with the theoretical degree predicted by Dr. Albert Einstein's theory of relativity, namely, 1.7 second of arc.

In the solar eclipse of 1918 the Lick Observatory photographed the stars in the region immediately surrounding the sun in order to test the Einstein theory, but the results seem not to have been published. There is presumably no question about the correct measurement of the English plates. The same results seem to have been obtained from the photographs which had been taken at Sobral in north Brazil and at the Island of Principi off the African west coast. Neither does there appear to be any alternate explanation of the phenomenon. Professor H. F. Newall, of Cambridge, is said to have suggested at the meeting that it might be due to an unknown solar atmosphere, further in extent than had been supposed and with unknown properties, but it is not clear how a hypothesis in itself unlikely would account for the deflections, if they are those called for by the Einstein theory.

It is further the case that the theory had already been confirmed by another astronomical fact, the motion of the planet Mercury, which accords with the theory of relativity, but can not be accounted for on the exact assumptions of Newton's law of gravitation. On the other hand, a shift of the lines in the spectrum toward red in a strong gravitational field, which the Einstein theory requires, has been looked for unsuccessfully.

The experiment of the English astronomers is in itself very simple. If the rays from the stars are deflected by the gravitational field of the sun, this can not ordinarily be observed, for it is impossible to photograph them in the sun's light. But at the time of a total eclipse the bright stars, far beyond the sun but near it in the firmament, can be photographed, and their apparent positions can be compared with the positions of the same stars when the rays do not pass near the sun. The change in the apparent positions of the stars, presumably through deflection of their light by gravitation, can thus be readily measured.

Sir J. J. Thomson, the president of the Royal Society, is reported to have said at the meeting that it was the greatest discovery in connection with gravitation since Newton enunciated that principle. This in itself might not mean much, for no discovery in regard to gravitation has been made since the time of Newton. But if the results lead to the acceptance of the whole theory of relativity, as developed by Einstein, then indeed not only our theories of gravitation and the ether, but our whole conception of space, time, mass and

motion must be altered more fundamentally than has ever before occurred in the history of science.

A clear account of the theory of relativity by Professor William Marshall, of Purdue University, will be found in the MONTHLY for May, 1914. Albert Einstein, then employed in the Swiss patent office, formulated the theory in 1905 with remarkable perfection in a short article entitled "Concerning the electrodynamics of moving bodies." In 1911 he published the paper which deduces the influence of gravity on the propagation of light which is said now to be confirmed by the astronomical observations. Dr. Einstein was appointed to a chair in the Zurich Polytechnic School and was later called to one of the research institutions established in affiliation with the University of Berlin.

The Einstein theory may be said to have had its origin in an effort to explain the experiment on the so-called ether-drift, made by Professors Michelson and Morley somewhat more than thirty years ago at the Western Reserve University. Michelson suggested that the negative result of the experiment could be accounted for by supposing that the apparatus underwent a shortening in the direction of the line of motion. Later Professor Lorenz, the Dutch physicist, assumed that everything gets shortened as it moves through space; that the 8,000 miles of the earth's diameter is shortened up by three or four inches, an amount sufficient to provide a scientific explanation for the failure of the Michelson and Morley attempt to detect that the earth was moving through the ether. Then Einstein proposed his generalization that it is impossible to detect the effects of motion, except when it is relative to another material body, or that it is impossible to detect the absolute velocity of any body through space.

Many queer things have been written and will be written in the daily press concerning the theory of relativity, but perhaps none more strange than the logical deductions from the theory. As an example, Einstein's words (as translated by Professor Wetzel in *Science*, October 3, 1913), in the paper of 1911, may be quoted:

> Give the watch a very large velocity (approximating the velocity of light) so that it travels with uniform speed; after it has gone a long distance give it an impulse in the opposite direction so that it returns to its starting point. We then observe that the hand of this watch during its entire journey to and fro has remained practically at a standstill, while the hand of an exactly similar watch which did not move with respect to the coordinate system (the sun or earth) has changed its position considerably.
>
> We must add: what is true for our watch with respect to time must also be true of any other enclosed physical system, whatever its nature, because in all our thinking the watch was introduced simply as a representative of all physical actions or occurrences. Thus, for example, we could substitute for the watch a living organism enclosed in a box. Were it hurled through space like the watch, it would be possible for the organism, after a flight of whatever distance, to return to its starting point practically unchanged, while an exactly similar organism which remained motionless at the starting point might have given place to new generations. For the organism in motion time was but a moment, if its speed approached the velocity of light. This is a necessary consequence of our fundamental assumptions and one which experience imposes on us.

THE DISINTEGRATION OF ATOMS AND ATOMIC ENERGY

THE theory of relativity, though based on physical observations and

mathematical equations, seems to carry us into a metaphysical region remote from our normal interests. The discovery of radio-activity has opened new fields for exploration yielding results almost incredible, but not removed from our ordinary conceptions and everyday interests. At the recent centenary commemoration of James Watt, it was suggested by Sir Oliver Lodge that if Watt were living to-day he would be directing his attention to discovering whether there are other stores of energy at present almost unsuspected. The fact was that contained in the properties of matter there was an immense source of energy so far inaccessible, but which he saw no reason why the progress of discovery should not make available. He referred to atomic energy which, if it could be utilized on an extensive scale, would, he believed, greatly ameliorate the conditions of factory life. There would be no smoke due to imperfect combustion and no dirt due to the transit of coal or ashes, while the power would be very compact and clean. Possibly there might occasionally be explosions due to the liberation of power more quickly than it was wanted, but in general he presumed that the conditions of utilization would be good.

Sir Oliver explained that the secret of this power began to be given away when radio-activity was discovered, and said that at present we were hardly at the beginning of its utilization. The discovery of radium, which soon followed, excited universal interest and aroused great surprise, because radium appeared to give off energy continually without being consumed. The truth was that it did disappear as it gave off its energy, but the disappearance was so slow and the energy given off so remarkable that it was not surprising that one was noticed before the other. The energy of radium, however, was not under control, and it went on emitting energy at its own proper rate without regard to accidental circumstances. What happened was that every now and then a particle was projected. The energy stored in an atom was something enormous, and if we could make the atoms fly off when we wanted there would be available a source of energy which would put everything else into the background. This energy was contained in all forms of matter and was not confined to radio-active substances. If a stimulus could be found the utilization of this source of energy would be possible. We appeared to be on the verge of utilizing a minute fraction of it, and it was this energy which had made wireless telephony possible.

Those familiar with Sir Oliver Lodge's communications with the spirit world may regard his information concerning the energy of atoms as equally speculative, but this is by no means the case. Sir Ernest Rutherford has recently given a lecture before the Royal Institution in which he described experiments which are incontrovertible even though the explanation that he adduces may not be final.

The swift α-particles and the high-speed electrons or β-rays ejected from radio-active bodies are by far the most concentrated sources of energy known to science. The enormous energy of the flying α-particles or helium atom is illustrated by the bright flash of light it produces when it impacts on a crystal of zinc sulphide, and by the dense distribution of ions along its trail through a gas. This great store of energy is due to the rapidity of its motion, which in the case of the α-particle of radium C amounts to

19,000 km. per second, or about 20,000 times the speed of a rifle-bullet. The energy of motion of an ounce of helium moving with the speed of the α-particle is equivalent to 10,000 tons of solid shot projected with a velocity of 1 km. per second.

Sir Ernest Rutherford found from the scintillations on a zinc sulphide screen that when an α-particle strikes an atom of nitrogen the latter is broken down and a long range atom, which is not nitrogen, arises from the collision. This atom is held to be a charged atom of hydrogen or an atom of mass 2. Sir Ernest says that taking into account the great energy of the particle, the close collision of an α-particle with a light atom seems to be the most likely agency to promote its disruption. Considering the enormous intensity of the forces brought into play in such collisions, it is not so much a matter of remark that the nitrogen atom should suffer disintegration as that the α-particle itself escapes disruption. The results, as a whole, suggest that if α-particles, or similar projectiles of still greater energy, were available for experiment, we might expect to break down the nucleus structure of many of the lighter atoms.

INTERNATIONAL SCIENCE AND THE WAR

AN appeal has been addressed to the members of the academies of the allied nations and of the United States by 177 members of the academies of neutral nations—Holland, Norway, Sweden, Denmark, Finland and Switzerland—represented in the International Association of Academies, the opening and concluding paragraphs of which are as follows:

In the autumn of 1813, when for years a most bitter war had been raging between France and England, the English chemist Humphry Davy set out for Italy via Paris. His biographer relates what follows about his experiences in the French capital: "Nothing could exceed the cordiality and warmth of Davy's reception by the French savants. On Nov. 2nd he attended a sitting of the First Class of the Institute and was placed on the right hand of the President, who announced to the meeting that it was honoured by the presence of 'le chevalier Davy.' Each day saw some reception or entertainment in his honour. . . . On Dec. 13th, 1913 he was with practical unanimity elected a corresponding member of the First Class of the Institute."

On October 2, 1918, when a most bitter war raging between France and Germany for four years had practically come to an end, it is stated in a meeting of the French Academié des Science, that "elle a été unanime à déclarer que les relations personnelles sont pour longtemps impossibles entre les savants des pays alliés et ceux des empires centraux," so that "nous devons abandonner les anciennes associations internationales, et en créer de nouvelles entre alliés avec le concours eventuél des neutres."

Whence this painful contrast? We should rather have expected the opposite, even without indulging illusions with regard to the progress of mankind during a hundred years. For there seems to be more room for generosity when the war's misery is past than when it is still raging; more too towards a defeated enemy than towards one who is still to be feared.

. . . .

Summing up what precedes we ask you earnestly and urgently: Recover your former selves. Recover the high scientific point of view which, on his deathbed, made Ampère say to a fellow worker: "il ne doit être question entre nous que de ce qui est

eternel!" Once more: we understand how your attention of late has been monopolized by what is temporal and transitory. But now, you more than all the others, are called upon to find again the way to what is eternal. You possess the inclination for objective thought, the wide range of vision, the discretion, the habit of self-criticism. Of you we had expected the first step for the restoration of lacerated Europe. We call on you for cooperation in order to prevent science from becoming divided, for the first time and for an indefinite period, into hostile political camps.

SCIENTIFIC ITEMS

WE record with regret the death of Charles Henry Hitchcock, for forty years professor of geology at Dartmouth College.

DR. SIMON FLEXNER, director of the laboratories of the Rockefeller Institute for Medical Research, Dr. Theodore W. Richards, professor of chemistry at Harvard University, and director of the Wolcott Gibbs Memorial Laboratory, and Dr. R. W. Wood, professor of physics in the Johns Hopkins University, have been elected foreign members of the Royal Society of London.

DR. FRANK SCHLESINGER, of the Allegheny Observatory, was elected president of the American Astronomical Society at the recent Ann Arbor meeting. Dr. Schlesinger succeeds the late Edward C. Pickering, who for many years in succession had been elected to this office.—At the October meeting of the executive board of the National Research Council Professor Vernon Kellogg, of Stanford University, was elected executive secretary of the council.

ANNOUNCEMENT is made that Mr. John D. Rockefeller has added $10,000,000 to his previous endowment of the Rockefeller Institute for Medical Research. This gift, the largest made by Mr. Rockefeller at one time to the institution, is to meet rapidly growing needs in its many lines of research and in making new knowledge available in the protection of the public health and in the improved treatment of disease and injury.

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